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Proceedings—Workshop on Engineering and Hydrology Research Needs for Phosphate Mined Lands of Idaho

Pocatello, Idaho, June 5-6, 1984

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EXECUTIVE SUMMARY

The western phosphate field, of which southeastern Idaho is a major part, currently supplies about 14 percent of the United States production of phosphate. Projections for the next 20 years are that demands will continue with possibilities of substantial growth with improved economic situations. Researchers, land managers, and mining industry officials have established strong cooperative ties and are optimistic about the future. Effective reclamation programs can improve both mining and reclamation operations.

This report is a result of a June 1984 workshop on engineering and hydrology research needs for phosphate mined lands of Idaho. Specialists from many agencies, universities, and companies reviewed the rehabilitation progress and explained ongoing research projects. The abstracts of these sessions are included in this report. The workshop participants then divided into four working groups to identify "knowledge gaps" that need the attention of future research. These groups were (1) coordination of mineral development with surface resource management, (2) mine plans, (3) risk analysis, and (4) mined land stabilization and costs.

SYMPOSIUM SUMMARY

ENGINEERING AND HYDROLOGY PRACTICES IN THE SOUTHEASTERN IDAHO PHOSPHATE FIELD

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INTRODUCTION

This paper attempts to summarize the present state of the art of hydrology and engineering practices in the southeastern Idaho phosphate field. The information presented is of necessity broadly stated and serves as background material for the research needs that follow this paper. Present engineering and hydrology practices generally followed by the industry are quite sophisticated, as shown by the demonstrated success of land reclamation and revegetation on mined lands. Such success cannot be achieved without good control of drainage and embankment design and construction. However, because of the size and scope of the phosphate mining operations, concerns with the operating costs and the stability and hydrology of affected lands persist both within the industry and by the land managers. This paper gives the reader an appreciation for the practices and the problems of engineering and hydrology, and provides a basis for increased understanding of the concerns of both land managers and the industry.

Climate

The climate in southeastern Idaho is strongly influenced by the north- and south-trending mountain ranges and valleys. These mountain ranges are almost perpendicular to the prevailing west and northwest winds. Variability of climate between valley and mountain locations is pronounced. Mean annual precipitation ranges from about 25 cm in some of the drier valley bottoms to about 127 cm in some mountain locations. Precipitation tends to increase with increasing elevation, but the relationship is variable depending upon the aspect, height of the ridgetops, slope steepness, and direction of the prevailing wind. Increased precipitation at the higher elevations is more pronounced in winter than in summer. Usually less than half of the annual precipitation falls during the warm season, May through October. During most of the cold season, November through April, precipitation falls as snow, the proportion of snow to rain increasing with elevation.

The growing season (nonfreezing period) averages 142 days at Pocatello, one of the warmest points in the western phosphate field. At many mountain locations the growing season is less than 60 days. Temperatures of less than 0 ^{0}C have been recorded during every month of the year at Conda, ID, and Afton, WY, both valley locations. Frost hazard persists all summer at all elevations over 2 100 m. Maximum summer temperatures are generally warm at all elevations, but large (19 ^{0}C) diurnal temperature ranges, caused by cloudless days and radiation cooling at night, are common. Minimum winter temperatures are influenced by arctic air masses moving down the western side of the Rocky Mountains. These air masses may bring several consecutive days of subzero temperatures. At Afton (1 864 m elevation) the record cold temperature is -48 ^{0}C.

Soils

For the most part, soils in the area have not been mapped in detail. There are at least 16 great soil groups in the area. These range from deseritic aridisols to the cold subhumid alfisols. The principal soils are the subhumid mollisols and the gray-wooded alfisols. On these soils, organic matter accumulates rapidly and the

soil surface horizons are thick and dark. On the steeper slopes the soils are the entisols and inceptisols. Most of the soils are residual and have developed from sedimentary parent materials--limestone, cherts, and sandstone. Soil pH is nearly neutral, ranging from slightly basic to slightly acid. Because surface mining for phosphate violently disrupts the surface soils, the properties of the underlying subsoils and parent materials become unusually important. Unfortunately, information on subsoils is even more sketchy than information on surface soils. However, it is important to note that subsoil phytotoxicity is rare to nonexistent.

Geology and Physiography

The operating mines in southeastern Idaho exploit outcrops of the Meade Peak Phosphatic Shale member of the phosphoria formation. These outcrops often occur along or near ridgetops and are the surface exposure of former blanket-type sediments that were deposited in a Permian sea 225 to 280 million years ago. They were subsequently covered by younger sediments and lithified. Later uplift, folding, faulting, and erosion of the younger rocks created the present outcrop pattern.

Sources of information about the regional geology are Mansfield (1927), Armstrong and Cressman (1963), Cressman (1964), Armstrong and Oriel (1965), and Mabey and Oriel (1970).

The area has many geologic faults that are young and potentially active. Movement of any one of them would not be surprising. Such movement would cause earthquakes that would be felt most strongly near the fault. Breakage of the land surface would also be possible. On the basis of historical earthquakes and the assumed locations of future earthquakes, there is less than a 10 percent probability that a quake of magnitude VIII, or greater will occur near Soda Springs during the next 50 years (Bones 1978). An earthquake of magnitude VIII did occur in the Pocatello Valley on March 27, 1975. Malad City, 23 km northeast of the epicenter, sustained $100,000 in damages.

Southeastern Idaho is characterized by north- and northwest-trending mountain ranges and valleys that form part of the middle Rocky Mountains physiographic province. The entire area is over 1 350 m high, the highest point being Meade Peak, about 11 km east of Georgetown. The peak rises to 3 035 m. The relief between Meade Peak and Bear Lake Valley is about 1 200 m. Local relief of 300 to 600 m is common. Folding of the rock layers early in the geologic history of the area, and subsequent block faulting parallel to the fold faces, produced the linear trend of sharply defined valleys and ranges, features similar to those in the Basin and Range physiographic province to the southwest of the area.

MINING METHODS

In southeastern Idaho the sedimentary beds have been severely faulted and folded by crustal deformation. Local sections may dip at any angle from nearly horizontal to vertical. Erosion has occasionally exposed the phosphate-bearing formations in narrow bands along the flanks of the simpler folds or in the irregular fringes of the more complexly folded and faulted areas. To mine the phosphate ore, the mine operators use either shovels and trucks or scrapers and bulldozers. The main bed ores, suitable for use in wet-process phosphoric acid plants, and furnace shale, used in electric furnaces for the recovery of elemental phosphorus, are selectively mined. Excessive amounts of calcium oxide, iron oxide, magnesium oxide, silica, and organic matter are detrimental to the refining process. Recognizing the need for uniform and uncontaminated plant feed, mine operators have developed the ability to selectively mine and blend large tonnages of varying grade phosphate rock.

Mining methods used in the western phosphate field are generally similar. Before a pit is opened the area is cleared. Merchantable timber is harvested while the rest of the vegetation is burned or pushed aside. Topsoil is usually not salvaged or stockpiled for later reuse. The topsoil is often thin, sometimes less than 15 cm. Frequently there is an abundance of middle waste shales within the mine profile that are not phytotoxic and provide an adequate, if sterile, rooting medium for revegetation. The texture of these middle waste shales is a gravelly silt loam or a gravelly sandy loam.

Pit excavation requires drilling and blasting. Overburden wastes are removed with large electric shovels and trucks or with self-propelled or dozer assisted scrapers. Large front-end loaders may also be used. Depending upon the need of the operator it is not unusual for a pit to be mined, temporarily closed, and then reopened at a later date.

Pit depth is determined by the continuity of mineralization, the degree of ore alteration by weathering, and the stripping ratio. The stripping ratio is a measure of how many units of waste overburden rock are removed for each unit of ore mined. From the unit cost of stripping and ore removal and the unit value of the ore, the economic mining depth can be calculated. Stripping ratios of 3:1 to 5:1 are common during the various stages of mining. In addition to economic factors, the eventual pit depth is governed by the stability of the pit walls and the groundwater conditions around the walls and in the pit.

The mineralized zones are selectively mined and transported to blending piles at the mine tipple or loadout facility and then further transported

to the processing plant. Winter weather conditions dictate that the ore be mined, transported, and stockpiled at the processing plant during the warm season. Winter handling of the phosphate rock in trucks or railroad cars is often unsatisfactory due to the ore freezing in the car.

Waste materials generated during the mining generally consist of shales, limestones, and chert. The chert rock varies but can be broken into two groups, hard chert and soft chert. The soft cherts could be classified as organic siltstone.

Three methods are used to dispose of waste overburden: (1) they are backfilled into an existing pit; (2) scraper built dumps are constructed in lifts from the bottom to the top; or (3) waste dumps are constructed by trucks end dumping over angle of repose embankments. Such embankments are then graded by bulldozers downward to the desired steepness and shape. Such waste embankments are constructed from the top downward. There is considerable gravity sorting of the rock material when a dump is constructed in this manner. Larger materials roll to the bottom while finer materials remain nearer the top. Gravity sorting is believed to promote mass stability within such dumps because of better drainage provided by the sorting. However, this construction method also results in low placement densities because most of the material receives little compaction effort. Scraper-built dumps constructed from the bottom to the top result in greater placement density, but this method is used less frequently than the other methods. This method is used primarily where a low, contoured dump is to be built, usually less than 750 thousand cubic meters.

Shaping and grading the slopes of waste embankments is done (1) to promote increased surface soil stability, (2) to permit revegetation of the embankment with farm-type equipment, and (3) to increase the visual qualities of the embankment by blending the shapes more neatly into the surrounding terrain.

LAND RECLAMATION

Land reclamation--the process of returning land disturbed by mining activities to productive uses--is strongly affected by engineering and hydrologic considerations. Reclamation planning starts early in the development of the mining concepts. Mining methods, haul routes, waste volumes, waste embankment locations and size, and so forth, all affect how and when the final reclamation is done.

Satisfactory land reclamation provides for land stability and the establishment of vegetal cover to build the soil, protect the soil surface, and restore vegetative production.

Revegetation

The Idaho phosphate industry has a good record of successfully revegetating waste embankments and other disturbed lands. Because of the low population density and the rural or wild nature of the phosphate mining areas in southeastern Idaho, reclaimed lands will normally be used for forage or browse production for sheep, cattle, and big game animals. On some sites timber production may be a long-term use. The land and streams are valued for their water yield and fishery resource. More intensive uses are not expected in the forseeable future.

The degree of success of a revegetation effort is strongly affected by preparation of the site. Site preparation includes shaping and grading to a desired slope steepness, ripping, topsoiling, and making the seedbed. Slopes steeper than about 3:1 are normally not safe for revegetation equipment because of the rollover hazard. It is often necessary to rip the surface materials of waste embankments to allow water, air, and root penetration into the waste. Ripping depth and spacing vary with the operators and the available equipment. Ripping to a depth of about 30 cm can be done with a large spring-tooth harrow set to run deep. Ripping more deeply than 30 cm requires rigid steel ripping tines. Topsoiling is an effective and desirable treatment for revegetation success. Topsoil, as used here, includes a variety of natural topsoils, shallow subsoils, and any of the soillike middle waste shales. Topsoil depths vary from about 0.3 to 1 m depending upon the site conditions and the availability of soil materials. Seedbed preparation usually consists of harrowing once or twice after the ripping operation. Both springtooth and vibrating shank harrows have given good results. Seeding and then firming the seed into the seedbed can be done with either a seeder-packer or a seed drill.

Fertilizer is required to promote rapid growth of newly seeded stands of grasses and forbs. Heavy grass stands are desirable both for soil protection from erosion and for additions of below ground organic matter to the waste. Fertilizer rates should be based on a fertility analysis of the waste material. Where shrubs are being seeded with grasses and forbs, the rate of fertilizer application should be reduced.

A large portion of the reclamation research in the western phosphate field concerns identifying plant species that are adapted to mining disturbances. Both native and introduced species have been used with success. Lists of adapted plant species have been published by Richardson (1981) and Farmer (1979). Seeding rates for fall plantings of grass and forbs on fertilized sites run from 28 to 45 kg of seed per hectare. Fall is the preferred planting season.

Soil Erosion

In most years the melting snowpack causes most of the soil erosional losses. However, the occasional high intensity summer thunderstorm can create deep rills and gullies in bare waste embankments. Some of these damaging storms may have fairly short return periods of, say, 2 to 5 years. The main difference in the erosion amounts created by snowmelt as opposed to a rainstorm is associated with the raindrop impact of the storm. Raindrops are an effective agent for detaching soil particles from the soil surface. Melting snow lacks this drop action. In addition to differences in soil erosion due to rainstorms versus snowmelt, there are large differences in erosion between bare and revegetated waste embankments. There are also significant differences in soil erosion due especially to slope steepness and secondarily to slope length and aspect.

Well-revegetated waste embankments with a slope steepness of about 3:1 exhibit low rates of soil erosion. Measurements conducted by the Intermountain Station have placed these amounts variously at between 250 and 1 100 kg/ha per year for moderate rainstorm or snowmelt events. These amounts are lower than would be expected on many farming operations. On the other hand, soil erosion rates on bare waste embankments with slope steepness varying from 4:1 to 2:1 can be dramatic. Measurements of erosion amounts range from 9 to 1 744 mt/ha per year. The average rate was 190 mt/ha per year. Fortunately, these rates of erosion are controllable by making provisions for the safe disposition of surface runoff waters and by prompt and serious revegetation efforts.

Mass Stability

Reclamation programs need to consider the long-term mass stability of overburden waste embankments. Some desirable characteristics of waste embankments are:

1. They should be engineered structures that provide for long-term stability with low maintenance.

2. They should not interfere directly or indirectly with the use of downstream resources.

3. They should provide for a level of land productivity comparable with, but not necessarily the same as, premining conditions.

To achieve these reclamation goals for waste embankments it is necessary to consider a variety of engineering and hydrologic concerns associated with the waste materials themselves as well as the physiography of the site receiving the waste and the nature of hydrologic and meteorologic events of interest.

WASTE EMBANKMENTS

Waste embankments are a significant feature of phosphate mining in southeastern Idaho. They range in size from a few thousands of cubic meters to more than 30 million cubic meters. Even larger embankments will probably be constructed in the future. Nearly all of the embankments can be classified into one of three configurations based on their relation to the natural topography: sidehill, head-of-valley fill, and cross-valley fill (fig. 1).

Evaluating Embankment Sites

This section presents some of the important mass stability considerations that are conditioned by the selection of the waste site. There are other considerations that operating companies use in site selection in addition to those associated with mass stability. Usually these additional considerations involve the capacity of the site to hold waste and the cost of hauling overburden to the site. Also important are the potential costs of mitigating environmental impacts arising from the waste embankment and the costs of reclaiming the embankment. However, we will consider only the following:

1. Natural site hazards
2. Shape and nature of the site
3. Geology and stratigraphy
4. Windward terrain, fetch, and topography
5. Aspect

<u>Natural site hazards</u>.--In the Idaho phosphate field the common natural hazards at a site are over-steep slopes, a propensity toward natural slides, shallow transient groundwater tables, and weak foundation rock.

Natural slope steepness is a key factor related to the occurrence of waste embankment movement or failure. Slides can only occur when natural slopes are steep enough for some combination of factors to produce a stress great enough to overcome the natural slope resistance to movement. Slope steepness is a key factor in selecting a location for a sidehill waste embankment. In any spoil mass with an upper surface that is not horizontal, shearing stresses develop internally that tend to move the upper surface downward. If the internal shear stress exceeds the shear resistance, movement will occur.

Landslides associated with mining activities have been noted in several cases. Some cases have been pit failures, probably due to unloading the foot wall. Other cases have been slope failures, probably associated with slope loading on inherently weak soils or with loading at too high a rate.

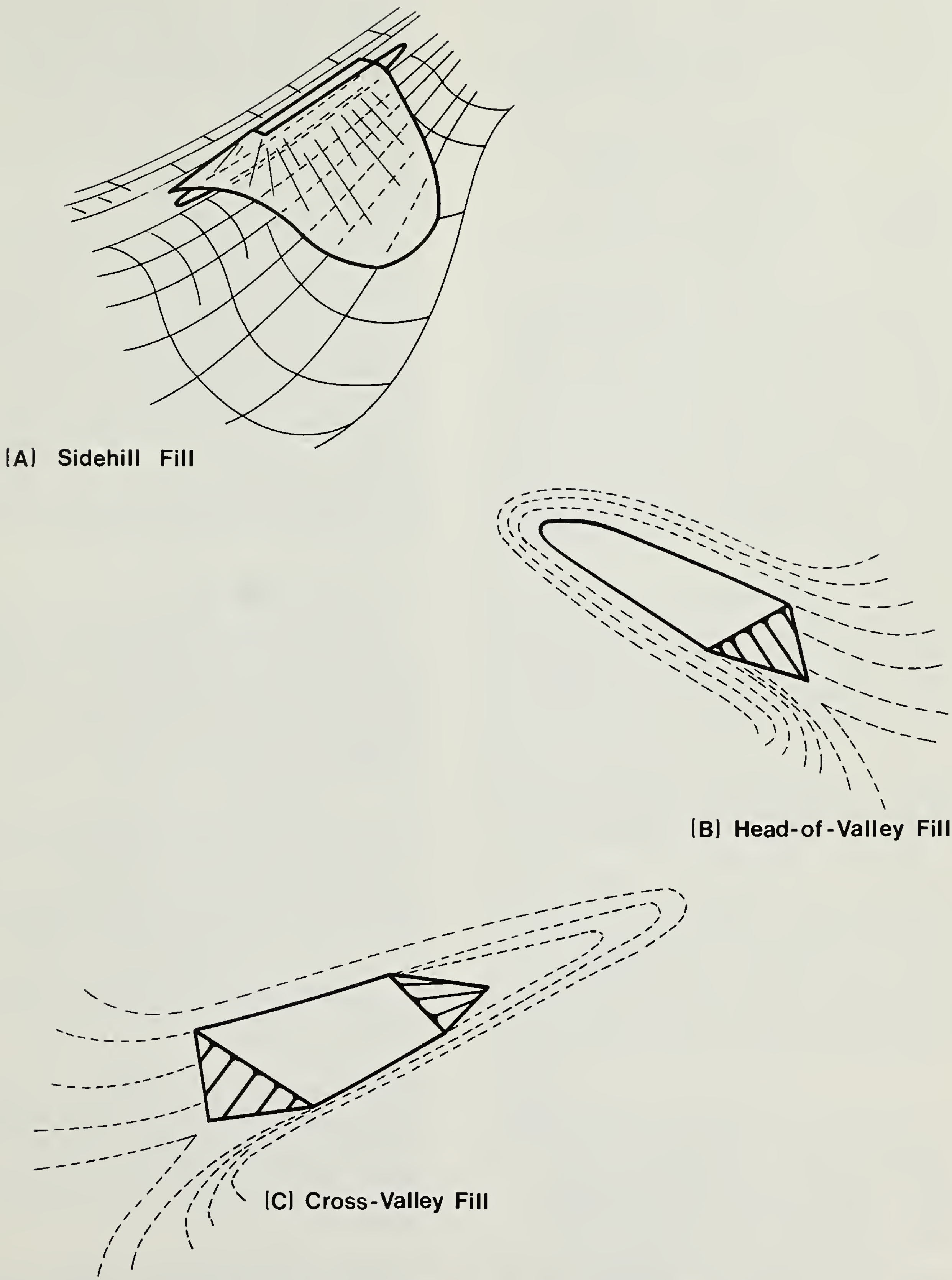

Figure 1.--Three commonly used configurations for overburden waste embankments.

Transient groundwater tables are common on valley sidehills during peak snowmelt. This is not necessarily a problem. However, groundwater can move from the sidehills into the waste embankments increasing the water saturation and pore pressures within the embankment. The known failures resulting from this mechanism have been small, less than 4000 cubic meters.

Failure in the foundation of waste embankments is not common. We only know of one instance. However, with the increasing size of waste embankments being built today, foundation investigations assume increasing importance.

Shape and nature of the site.--Because cross-valley fills are relatively new in the Idaho phosphate field, there is not a lot of accumulated experience with them. Also, the cross-valley fills tend to be larger than either sidehill or head-of-valley fills. However, assuming no foundation failure and that failures originate within the waste material itself, then those embankments that must transmit the least water have the most potential stability. From most stable to least stable these would be: sidehill, head-of-valley, and cross-valley. This ranking appears justified by observational data, but the number of cases is too small to make a sound judgment.

The shape of the receiving site needs to be evaluated. If we consider the plane slope a benchmark against which to measure other slope shapes, convex slopes are less stable and concave slopes are more stable. In unstable areas with a history of landslides, a frequent site for starting such slides is just below a convex break in slope in the head of a small drainage.

Geology and stratigraphy.--Slopes that are nearly parallel to bedding planes of sedimentary parent materials, or parallel to the direction of jointing and fracturing of any parent material, are susceptible to landslides.

In the parallel situation, stratigraphy promotes sliding in two ways. First, the surface of the parent materials and interfaces between strata within the parent materials provide zones of weakness and ready-made failure surfaces. Second, parallel bedding with the surface tends to concentrate and return percolating water back to the surface. Water coming to the surface may produce excess pore-water pressures, lubricated slip surfaces, or both.

In the situation where the stratigraphy is more or less normal to the surface, the stratigraphy contributes little to possible failures or landslides. This is because weakness in the bedding plane is normal to the direction of failure. Such slopes are also more stable because the strata tend to direct water down the bedding planes away from the surface.

Windward terrain, fetch, and topography.--In the upwind direction, the shape of the ground surface, intervening topographic barriers, and snow fetch distance all influence the amount of snow accumulation and the occurrence of snowdrifts. As a general rule in the Idaho phosphate field, minimizing the amount of subsurface water within a waste embankment is desirable, meaning we should try to limit the amount of snow accumulation on the waste embankment surfaces.

Aspect.--In general, south aspects do not have as much difficulty with embankment stability as do north or east aspects. This difference in stability is associated with the influence of aspect on snowmelt rates. On south aspects snowmelt typically starts in February. Melt rates are slow because of the cold night temperatures. The snowpack is often completely gone by the second week of April. On north aspects snowmelt usually starts in March and peak melt rates usually occur in late May or early June. This difference in melt rates can be accentuated by a long, cold spring season that delays snowmelt until the onset of hot weather. Not only are peak melt rates higher on north aspects than on south aspects but north aspects generally accumulate more snow. These factors generally mean that north-sloping embankments must transmit more water than south-facing embankments.

Design and Construction

A brief description of the methods and techniques of constructing waste embankments has already been given under "Mining Methods." Here we want to look more closely at the general information requirements and the techniques used to design embankments. At least in the larger embankments, a usual first step is to develop stability analyses.

After a site has been chosen to hold the overburden waste material and the necessary site investigations have been conducted, stability analyses are performed. The analysis results in a factor of safety against sliding, which is the ratio of forces resisting failure to the forces that tend to cause the completed structure to fail. Stability analyses use soil, spoil, and rock strength values obtained from laboratory tests. The anticipated soil water or groundwater conditions within the embankment are also considered. These strength values and conditions of the soil water content, along with the various geometric configurations proposed for the embankment, are used in the factor of safety analysis. In a typical analysis the proposed configuration of the embankment including the outslope of the embankment is varied until an appropriate factor of safety is achieved. Usually the degree of water saturation is also considered as a variable to see what effect saturation has upon stability.

The most likely shapes and positions of the slip surfaces are determined by the engineer, based largely on observations made during the site investigation and on skill and engineering

judgment. Various geometries of potential slide masses are investigated until the geometry that provides the lowest acceptable factor of safety is determined. A sloping mass on the verge of failure has a factor of safety of 1.0. If an analysis indicates a factor of safety of less than 1.0, a slide would be highly likely. Calculations of geometric configurations giving factors of safety greater than 1.0 provide the basis for an acceptably safe embankment.

Minimum acceptable factors of safety probably should be determined on a case-by-case basis. Some guides may be useful. For earth-fill dams in a steady state seepage condition--a full reservoir--a factor of 1.5 is generally acceptable. It seems reasonable to assume that this would be the upper limit in the factor of safety for a waste embankment. A lower factor of safety than that required for long-term stability is also tolerable during the construction period. On most sites factors of safety of about 1.15 for construction and about 1.3 for long-term needs seem reasonable.

In summary, the steps leading to an evaluation of the factor of safety of an overburden waste embankment are (National Research Council 1981):

1. A feasible failure surface is selected, according to the layering and strength of materials in the slope. An experienced analyst can predict the most likely places for a slip surface by examining slope cross-sections that show the distribution of soil/rock properties and the distribution of pore-water pressures.

2. Forces and moments acting on each element of the slope are calculated according to the analysis method of choice. We will not discuss methods here. In any case, equations of force and moment equilibrium are solved for the combination of geometry, material strength, and pore-water pressures selected.

3. The factor of safety is computed by comparing the shearing resistance necessary for equilibrium to the available shear strength along the selected failure surfaces.

4. Steps 1 through 3 are repeated successively with different failure surfaces until the critical surface--the one with the lowest factor of safety--is located.

Of course, all of the factor-of-safety information assumes that adequate drainage of free water on or within the embankment is provided. In the case of a cross-valley fill, the additional complication exists of transmitting a live stream through the base of the embankment.

Information Needs

Information needed for planning and managing waste embankments in the Idaho phosphate field is suggested in table 1. Three categories are used for each item. While the elements listed in table 1 are suggestive of the data needs, the list may not be all-inclusive and the categorical needs are only approximate.

Table 1.--Information needed for planning and managing embankments

Element	Soils	Bedrock	Spoil
Stratigraphy	x	x	s
Geologic structure	-	x	-
Lithology including spoil	-	x	x
Aquifers	-	x	s
Springs	-	x	s
Unit thickness	x	x	x
Texture	x	s	s
Grain size	x	s	s
Weathered thickness	-	x	-
Weathering potential	-	s	x
Mineralogy	-	s	-
Clay mineralogy	s	-	o
Slaking character	-	s	s
Soil dispersion	-	-	s
Density	o	-	s
Rock soundness	-	s	x
Rock quality	-	s	x
Rock broken size distribution	-	s	x
Unconsolidated strength	o	-	s
Atterberg limits	o	-	-
Water content	-	o	s
Pore water pressure	-	-	s
Water/density relation	s	-	s
Permeability	o	o	s
Shrink/swell	o	-	o
Soil classification	o	-	-
Soil-rock analysis			
P,K	o	-	x
Other elements	o	-	s
pH	o	-	o
Salinity	-	-	o
CEC	s	o	s
Total carbonates	-	o	o
Organic content	s	-	o
Groundwater			
pH	-	-	o
TDS	-	o	s
Suspended solids	-	-	s
Hardness	-	-	o
Temperature	-	-	o
Chemicals	-	-	o

Key:
x Data considered to be necessary at most sites
s Data that might be selectively necessary
o Data that might be occasionally necessary
- Data not generally needed.

HYDROLOGY AND DRAINAGE OF EMBANKMENTS

The hydrology of the forest and range lands of southeastern Idaho has not been intensively studied. Hydrology studies and acquisition of hydrologic data on mined lands have, for the most part, been started only since 1977. Although the number and scope of hydrology studies in the Idaho phosphate field have been limited, our knowledge of the hydrologic response to mining disturbances is expanding at a good pace.

Southeastern Idaho has a poor hydrologic data base. With a single exception all of the phosphate mines are north and east of Soda Springs. The closest weather station is at Conda. The long-term annual precipitation at this station is 48 cm. However, this value may or may not be representative of the precipitation at the mine areas. Generally the mines lie at higher elevation and receive substantially greater snowfall than either Soda Springs or Conda. Precipitation records have been kept since 1980 by the Intermountain Station (Farmer) at the Dry Valley Mine at an elevation of approximately 2250 m. For the water years (October 1 to September 30) 1981, 1982, 1983, and 1984 the recorded amounts were 44, 83, 80, and 84 cm, respectively. Reliable records of streamflow in the mining area are limited to the Blackfoot River. Records in smaller tributary watersheds are almost totally absent except for a station on Maybe Creek operated by the Intermountain Station.

Infiltration

The rates of water infiltration into waste embankments has been a source of interest and misinformation for some time. Only a few years ago, embankments were sometimes described as impermeable with leaks. We now can state with confidence that embankments are not impermeable (Knopp and Farmer 1980; Kotansky 1984). Because infiltration is a surface phenomenon, it is not surprising that infiltration shows a large variation with surface materials. Several types of middle waste shales that were used as surface dressings on waste embankments have been studied. Infiltration varied from 2.4 to 4.4 cm/h, a surprisingly narrow range of values. Several "chert" materials have also been studied. These materials would probably be better classified as hard or soft siltstones, but "chert" has become common usage in the industry and will be used here. Finely fractured chert, about 5 cm minus, has high infiltration rates with uncompacted areas running in excess of 20 cm/h. Compacted chert, as in roadways, is not much less, perhaps 19 cm/h. As a comparison, some relatively undisturbed forests in the area will run about 24 cm/h. These are typical infiltration rates.

The complement of infiltration is surface water runoff. While the middle waste shales are used for surface-dressing for revegetation, their relatively low infiltration rates will produce more runoff and soil erosion. We would also speculate that the infiltration rates on middle waste shales will increase with the time since establishment of good vegetal cover. High infiltration rates on the chert are not without drawbacks. High infiltration rates mean that more water is transmitted into the interior of the waste embankments, with possible adverse influences on pore-water pressures and mass stability.

Groundwater

There is little doubt that overburden waste embankments accumulate large volumes of water. During snowmelt the surface 6 m of waste material approaches a fully saturated condition. Phreatic surfaces--free water surfaces--have also been observed within embankments. However, these facts do not necessarily indicate a groundwater condition in the usual sense. For instance, the transmissivity of the material and the volumes of water are such that little or no water could be pumped from the waste materials. The influence of this water within the waste materials upon positive pore-water pressure is probably slight under most conditions. Since 1980 in several arrays of multiple piezometers to depths as great as 45 m, I (Farmer) have been unable to measure any significant pore-water pressures.

Snowmelt does add considerable water to waste embankments. However, this is a transient condition. Normally, embankments will contain a maximum amount of water in late May or early June. This water will drain down into the waste materials and probably out into the fractured bedrock until the following recharge or snowmelt. Late February or early March is normally when embankments hold the least amount of internal water.

However, internal soil water in waste embankments is not entirely innocuous. Many small shallow mass soil flows have been initiated by saturated surface soils on waste embankments. Typically, these soil flows are small, under 4000 cubic meters. They most frequently occur on slopes steeper than 3:1, and the depth of failure of about 1 meter. The potential for more destructive flows of this type has not been evaluated.

Water Budgets

One of the authors (Farmer) has collected some water budget data but has not yet published them. The highlights of that data are presented here.

This work was done on a small scraper-built embankment of about a 195 thousand cubic meters. The embankment was entirely surfaced with middle waste shales and vegetated to a heavy stand of grass and forbs. The embankment is in the bottom of an ampitheater-like bowl and has a watershed of 15 ha above it.

Precipitation on the area during the 1978 water year was 72.4 cm. This amount was augmented by an additional 55.3 cm of water that moved through the embankment as lateral subsurface inflow from above, and an additional 15.3 cm of water transported onto the embankment as blowing snow. The total water that was transmitted by the embankment was the sum of these three components, or 143 cm.

This water was disposed of in several ways. The most important were evapotranspiration (68.3 cm), surface runoff (33.0 cm), and deep seepage (38.4 cm). The rest of the water was involved as slight changes in soil water storage.

While these data may not be representative of all waste embankments, they are probably representative of scraper embankments. Their major importance is probably as an insight into the hydrologic functioning of such embankments. They are useful in thinking about revegetation plans and sediment trapping measures and devices.

Water Quality

Water quality has, to date, never been a serious concern. However, the available documentation will be examined briefly. Water quality was determined in 1983 for the water emerging from a large embankment and for a small permanent stream downstream from an active mining operation (table 2).

Table 2.--Water quality analysis conducted on mining affected samples collected November 1983, mg/liter

Element	Embankment	Stream
Alkalinity	157	141
Aluminum	<0.1	<0.1
Beryllium	<0.005	<0.005
Boron	<0.02	0.022
Calcium	117	88
Total carbon	1.7	3.2
Chromium	<0.025	<0.025
Electrical cond.	831	633
Iron	<0.02	0.053
Magnesium	25	18
Manganese	0.009	0.021
Nitrate	3.9	2.0
Nitrite	0.002	0.008
Dissolved oxygen	8.2	7.5
pH	8.3	8.6
Orthophosphate	0.0316	0.0432
Total phosphorus	0.0639	0.0648
Potassium	1	1
Silica	7	7
Sodium	5	4
TDS	489	353
Suspended solids	5	29
Total solids	509	383
Temperature, celsius	3.0	4.5
Zinc	<0.005	<0.005

Note: Electrical conductivity units--micromhos/cm pH in standard units.

These water samples show very acceptable quality; they are very near the quality of potable water. Platts and Martin (1978), studying water quality in the mining area with respect to the fishery, concluded that mining had not degraded the waters in the area for either fish or benthic stream organisms.

Drainage

This section discusses three types of drainage: (1) drainage of surface water runoff, (2) drainage of water within waste embankments, and (3) drainage of live streams through french drains in the case of cross-valley fills.

Controlled drainage of surface water runoff on the mining areas, including waste embankments, is important. Today drainage controls are well understood and the occasional mistakes that arise can usually be attributed to the new or careless equipment operator. Today's understanding has developed from the mistakes of the past. Two difficult lessons come to mind. First, it is invariably a mistake to concentrate water on waste embankments in ponds or in contour trenches. Several failures and near failures of waste embankments have resulted from violating this rule. Second, ditches on-grade that are used to provide drainage will usually freeze and ice over. The operation of on-grade ditches is improved by burying perforated plastic drain pipe in the bottom of the ditch; 20-cm pipe would be adequate for most cases. Roads are another source of runoff that should be mentioned. Due to Mine Safety and Health Administration (MSHA) safety regulations regarding road berms, many roads become open conduits carrying large amounts of water. Large amounts of sediment may also be carried.

Disposal of this water and sediment is a problem for the industry. However, disposal of water within waste embankments has not been a significant problem for the industry. Where embankments are constructed by end-dumping from considerable height, the gravity sorting results in the coarser rock going into the base of the embankment. This size gradation apparently provides adequate drainage as there is no evidence of a water buildup in such embankments. Excessive pore-water pressures, if they ever develop, will probably come from a large rainfall event with a long return period.

Cross-valley fills are new to the Idaho phosphate mining industry. Only one such fill has been built, another is under construction. Both of these embankments will use the french drain or rubble drain to transmit streamflow through the base of the embankment. There are three concerns with french drains: (1) the capacity of the drain to transmit flood water, (2) the rate at which water can enter the upstream end of the drain, and (3) the possibility of the drain plugging with sediment at some time in the future. These concerns will be briefly considered.

Drain capacities are controlled by the size, or cross-sectional area, of the drain itself, the hydraulic gradient, and the transmissivity through the drain. With these in mind and with the intent to build drains with large capacity, we need to be sure that the drains are generously sized and constructed of coarse, durable rock. The cross-valley fill and french drain at the Conda Partnership's Dry Valley Mine appears to meet these guides. Although the hydraulics of this drain are still under study, the drain capacity is estimated to exceed 10,000 cubic meters per hour. The upper bound of the capacity is not known. At any rate, this is a substantial capacity.

The second concern, the rate at which water can enter the drain, is explained simply. In a large flood, say with a return period of 100 years or more, can all of the flood flow enter the drain simultaneously? If not, where does the rest of the water go? Even a drain with a substantial capacity may not be able to transmit a flood crest through the drain without any overflow. One possible solution to this problem is to truncate the upper end of the embankment. This creates a temporary reservoir that will hold the excess flood volume and drain it off over several hours or several days. This approach will make a large and significant reduction in the danger of a cross-valley fill being overtopped.

The danger of plugging a french drain with sediment does not appear to be large. However, it should be plain that the result of plugging would be catastrophic. The entire structure of 30 to 40 million cubic meters could be lost. In normal conditions of streamflow and sediment loads in streams, the life of a drain is expected to be long, thousands of years. But the vagaries of nature dictate that conditions will not always remain normal. A fire on the watershed above a cross-valley fill would put excessive sediment into the drain. One way to mitigate this is to cover the upstream end of the drain with one of the geotextile filter cloths. The temporary reservoir mentioned above will also tend to trap sediment. We all need a better solution to this problem.

SEDIMENT TRAPS

In the Idaho phosphate operations the most common method of trapping sediment is by use of the sediment pond. For the most part the ponds work well, trapping nearly all of the sediments with the exception of the colloidal particles and clays. Trap efficiencies have not been studied. However, due to the mountainous terrain and narrow valley bottoms, sediment ponds tend to be undersized with retention times that are too short. Sediment ponds also require such maintenance as dredging out when the pond is about two-thirds full. Sediment ponds on phosphate mines tend to be unmaintained or undermaintained. Research and development into sediment ponds that are easier to maintain and that increase retention times would be of significant benefit.

Other means of sediment control have been tried. One method that held some promise, at least on paper, of reducing cost while still trapping sediments was the gravel filter blanket. Experience with this means of sediment control has not been good and it cannot be recommended.

FLOODS IN SOUTHEASTERN IDAHO

Hydrologic phenomena are erratic in both time and space. Therefore, averages of hydrologic data tend to be misleading because the average is rarely realized. Usually the extreme event is of the greatest interest to society in general and to design engineers in particular. Flood frequency analyses of streamflow records help the hydrologist determine the potential flood risk and the design engineer to produce efficient designs for hydraulic structures, including waste embankments and drainage systems. However, this job is severely hindered by a lack of streamflow data. This creates uncertainty and inconsistencies between the results of different analysts and different methods. Part of the difference is due to the manner in which floods are conceptualized. In southeastern Idaho three flood generating mechanisms operate: (1) rainfall, (2) snowmelt, and (3) rain-on-snow (Kjelstrom and Moffatt 1981). In most years the peak flow, or annual flood, is generated by snowmelt. It also seems certain that the exceptionally rare flood (1000-year flood) will be generated by rainfall. Somewhere in between these extremes will lie the rain-on-snow floods. It seems reasonable to assume that the 100-year flood will be generated as a rain-on-snow event.

South Maybe Canyon is a small watershed that contains a perennial stream, Maybe Creek. This watershed is of interest because it contains a cross-valley fill of about 30 million cubic meters. The magnitude of floods traveling down Maybe Creek has been estimated 18 times. Depending upon the assumptions of the analyses and flood-generating mechanisms used, the estimates have been quite variable. Of these 18 estimates, 12 were estimates of the 100-year return period flood. The watershed area above the embankment is 430 ha. The range of estimates for flood volumes is from 2 to 53 hectare-meters. Five snowmelt floods were computed; estimates range from 2 to 5.5 hectare-meters depending on the estimate of the 100-year snowpack and the resulting melt. Two estimates of rain-on-snow yielded values of 14 and 16 hectare-meters. Based on channel geometry and capacity, 100-year estimates gave values of 5.5, 7, 8, and 9.5 hectare-meters. Finally, one rain-on-snow flood event that followed a hypothetical forest fire on the watershed yielded the 53 hectare-meters estimated flood volume. The great variation in these estimates is due to the difference in assumptions associated with each estimate.

However, the important point is not associated with the flood volumes, but rather is that if cross-valley fills are designed to impound/transmit approaches to hydrology and stability problems, we do not need to reinvent the wheel.

The following points are germane:

1. We need to investigate alternative practices for waste disposal. More specifically (a) angle of repose toe slopes on waste embankments at selected sites, (b) improved foundation preparation and keyways, perhaps combined with the point above, and (c) size of waste embankments--what are the tradeoffs between one large embankment or many small ones?

2. We need to investigate subsidence and creep in large waste embankments.

3. We need to begin research and development into a framework for evaluating the risk and uncertainties associated with the stability of large overburden waste embankments.

4. We need to investigate potential flood flows in ungauged watersheds and start discussions on the appropriate return periods to consider when planning for the drainage of mining disturbed lands.

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ABSTRACTS

RECLAMATION STANDARDS AND OBJECTIVES

Tom Roederer, Deputy Regional Forester
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As the need for phosphate and other minerals continues to expand, it is important we meet to share our concerns. I will discuss the standards and objectives for reclamation from the perspective of a land manager.

The state of affairs in reclamation is: "We are not farming as well as we know how to farm." We are not using our technology and know-how in many areas, and sometimes we miss the scientific approach.

I'd like to leave these points with you:

1. Mining is an interim use of the land. From the land manager's perspective, mineral activity involving a 30-year to 40-year operating plan is not out of the ordinary and is perceived as an interim use of the land. A mineralized area has a premining mix of uses, a period where mineral activity is part of the crop, and then a period of postmining where the land has other uses. The principal difference is time.

2. Reclaimed land is as much a result of mineral activity as is the ore. Thinking of reclaimed land as a result of a product of mining may be new to some of you. However, I suggest it is valid.

3. Large surface mining operations offer an opportunity to reshape and revegetate land to meet future needs. In other National Forest activities, we only alter the vegetation of the immediate surface of the land. In surface mining, however, we actually create new landforms--some of considerable size. This provides an unusual opportunity for the land manager. If we do it right, "we can have our cake and eat it too"--extract ore for today's needs and reshape the land for the future.

4. The direction for reclamation should come from long-range plans. Management direction for the postmining period is critical. At the outset of mining, we need to envision and decide what the end result will be. The Forest Plan should prescribe the mix of uses expected for both the mining and postmining periods. The planned reclamation needs to be designed to return the land to a prescribed condition accommodating the desired postmining use.

5. Site-specific reclamation objectives ensure that the reclaimed site supports Forest Plan direction. The reclamation objectives need to identify the specific mix of uses to be accommodated on the mined area. These may or may not be the same uses that were there before or during mining.

6. Performance standards ensure that reclamation objectives are satisfied. Standards are needed to ensure the desired end results for such factors as steepness of slope, amount of ground cover, water quality, and visual expectations. We need continuing support from the research community. Development of standards at some defined level of risk is needed to guide reclamation activity. Finally, we need to monitor and evaluate our reclamation efforts over the long term.

I challenge you to use this approach or improve on it by providing a better one.

MITIGATION OF LONG-TERM LOSS OF SURFACE RESOURCES: THE PURPOSE OF THE IDAHO SURFACE MINING ACT

Stanley F. Hamilton, Director
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Boise, ID

I would like to discuss the essence of the Surface Mining Act: what it's supposed to do, where it's working, where it is not working, and what I would like to see happen in the future.

In my opinion, there are three standards that all mined land reclamation projects must meet:

1. Public safety (gentle slopes)
2. Land surface stability (gentle slopes, vegetative cover)
3. Maintenance of water quality (gentle slopes, vegetative cover, reduction of erosion)

One major problem with the act is that certain operations were "grandfathered" when the law was enacted. An excellent example is the operation on State land called the Bovill clay pits at Bovill, ID. This site has been a scar on the landscape for years. It's not subject to the law, and the State lease, which predates the act, requires only a passing effort toward reclamation. Even if the project were covered by the act, it's doubtful if the reclamation could be done for the $750 per acre bond authorized by this outdated statute.

Therefore, I am pleased that Simplot Company, the operator of this lease, is voluntarily and at its own expense reclaiming this site. Simplot's work is to be commended.

The statutory bond limit of $750 per acre is a source of major concern to me, and each year that costs increase, the problem compounds. Right now, it's virtually impossible to reclaim small sites for $750 per acre. Nor could the Idaho Department of Lands handle any unusual chemical problems we might find in an inherited reclamation project.

I believe the bonding provisions of the Surface Mining Act are inadequate, and I seek your help in making them more reasonable in a manner similar to last session's changes in the Placer Mining Act.

Also, the exploration provisions of the Surface Mining Act are weak and need to be strengthened. An example of the problems we have encountered is the case of Abella Resources, a Canadian company that has been exploring for molybdenum on Scott Mountain, east of Garden Valley in Boise County. The company has simply walked away from its project without any effort to stabilize or restore the areas it disturbed--mostly roads not covered by the act. The Forest Service had a small $5,000 to $6,000 bond on the project that was barely adequate to water the roads and seed the slopes.

A similar project by Financial Design, a now defunct company from Boise, occurred about 18 miles east of Boise on Blacks Creek. The company was exploring for gold on Forest Service land in an area known to have low grade deposits. The company filed no plan or notice with the Forest Service and posted no bond. Virtually all of the work involved roads that were not covered by the Surface Mining Act. Before work began, the entire hillside was well-vegetated and stable. Road construction has caused extensive slope failure and subsequent denuding of the hillside.

To my mind, these projects demonstrate a clear need for more control over road construction activities in mining exploration projects.

Again, I seek your help in amending the law to deal more effectively with this type of activity.

One of the standards for a successful reclamation project is maintenance of good water quality. Properly constructed settling ponds are one way to achieve and maintain acceptable water quality.

Unfortunately, ponds that were at the Golden Reef Mine did not achieve that goal. In July 1981, Dewey Mines, predecessor to Golden Reef, had a major leak in its ponds resulting in excessive turbidity in more than 80 miles of Mule Creek, Monumental Creek, Big Creek, and the Middle Fork Salmon River. Dewey Mines, to its credit, worked hard to solve the problem. First, the company built additional ponds. Unfortunately, the liners sagged and leaked, and that avenue had to be abandoned.

When Golden Reef bought the mine, it completely redesigned the mill to significantly reduce the amount of process water needed. The company was successful enough that it was able to close the ponds and restore the land to near its original contours. The hill is relatively stable now, and water leaving the area is reasonably clear. All told, the company spent more than $100,000 in efforts to solve the leakage problem and reclaim the ponds. The State holds a $25,000 bond for the entire project.

Again, it's obvious additional bonding is required.

There also exists an apparent lack of authority to regulate reworking of old dumps and tailing piles. I understand that prelaw dumps and tailing piles are exempt from reclamation plans when the dumps are reworked. Such projects often involve many acres and much surface disturbance. I fail to see why such projects should be exempt from the law when new work occurs.

I seek your help in amending the law to authorize regulation of the surface effects of underground mines and the reworking of prelaw dumps and tailings.

Inspection fees are currently disparate with fees charged for inspecting placer mining operations. As you know, placer mining fees were recently changed and surface mine inspection fees should soon be changed to reflect equivalency.

The terms of the Surface Mining Act are no better than the enforcement that exists. Under my direction, the Idaho Department of Lands will provide firm, fair enforcement. We will almost certainly be aggressive in dealing with problems that "fall through the cracks" or are uncertain in terms of application of the law. The department will not be unreasonable in its enforcement activities.

In general, I believe that the terms of the Surface Mining Act are being met by the large mining companies, and their efforts are to be commended. On the other hand, the terms and intent of the act are not being met by many small miners and by many exploration operations. Nor are the objectives of the act being achieved at the surface of many underground mines or during the reworking of prelaw dumps and tailing pipes.

Mining is an important industry in Idaho, and we want it to continue as a viable and profitable enterprise.

The essence of the Idaho Surface Mining Act is the message:

BE A GOOD NEIGHBOR-- <u>CLEAN UP YOUR MESS!</u>

Our Department's mission is to ensure that the mining industry accomplishes that cleanup and in the process maintains public safety, land form stability, and good water quality.

PHOSPHATE LEASE FORMS, TERMS, AND STIPULATIONS

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Following the completion of the phosphate regional environmental impact statement on southeast Idaho phosphate, the Bureau of Land Management, the U.S. Forest Service, and the U.S. Geological Survey were faced with taking action on a variety of issues that included the 20-year phosphate lease readjustment and the preference right lease applications.

To begin action on the readjustments, the three agencies and industry representatives met in February 1978 at Pocatello to outline their strategy. The agency representatives agreed that a new lease form needed to be developed. A new phosphate lease form was issued by the BLM in September 1980. This form was never used in Idaho. A meeting in early 1981 covered the lease form, followed by the phosphate industry (through the Idaho Mining Association) submitting comments on the form in mid-1981. Another agency-industry meeting in fall 1981 covered the industry comments. A proposed phosphate lease form was developed, submitted to industry, and industry returned comments in mid-1982.

The decision then at the Washington level (Department of the Interior and the BLM) was to develop a "generic" lease form for solids minerals rather than proceed with a phosphate lease form. The generic lease form was published in the Federal Register in April 1983. Industry submitted comments on the generic form, and the final form was published in March 1984.

In March 1982, the BLM published proposed rules for the 43CFR Parts 3500, 3510, and 3520, mineral leasing regulations. In July 1982, industry submitted its comments. Because the lease form terms are drawn from the regulations, the new generic lease form and the leasing regulations were developed together. The final regulations were then published in April 1984, about 6 weeks after the lease form was published.

TRADEOFF EVALUATION: ACCUMULATIVE EFFECTS OF MINING AND POSTMINING LAND USES

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Soda Springs, ID

From my District Forest Ranger's perspective, I will discuss three areas of concern about minerals management and mining activities: (1) tradeoff evaluation, (2) accumulative effects of mining, and (3) postmining land uses.

Some people, including myself, dislike the term "tradeoff." This is because of its negative connotation, that in a tradeoff situation there will be something lost or given up. In administering the National Forest system lands, I would rather evaluate the compatibility of the various uses and consider the ability of the ecosystem to adjust to the various impacts. Many activities even have a symbiotic relationship and actually are an asset to each other. Following are a few examples:

1. The cooperative wildlife-phosphate study actually found that mining impacts, although disruptive, are not entirely destructive, and that wildlife are capable of adjusting to mining operations.

2. A major impact in 1983 was the construction of a 26-mile long slurry line from the Smoky Canyon Mine (J. R. Simplot) to Conda, ID. Work was scheduled to avoid elk-calving areas during calving periods and to avoid major stream crossings during spawning or high water.

Mining activities, if planned properly and completed according to plans, need not be destructive to other values and resources but are in fact compatible.

On the Caribou, 20,000 acres of National Forest system lands are under phosphate lease. Many more acres are now being considered for lease. Individually, any one lease or mine area is not a significant impact, but when all leases are looked at, they could show a major impact.

For that reason, extra care must be given in several areas:

1. Special stipulations to meet known site-by-site needs must be included on lease stipulations.

2. Operating plans must be based on sound exploration data, including drilling, pits, and geology. Then the plans must be followed.

3. To lessen the resource impacts, one mine area should be completed, including rehabilitation, before proceeding to a new mine area.

4. Transportation needs are a major impact and should be planned thoroughly and carefully. Should conveyor belts, truck haul, railroad, slurry line, or some other method be used to gain access and transport ore?

Tom Roederer has talked about reclamation standards. I would like to add that postmining land use is occurring. Wildlife seek out and use the reseeded areas, often close to current, active mining operations. In 1983 we released the mining company of responsibility for two mine waste dumps and allowed the grazing permittee to feed the area with sheep. One major problem with grazing is that in many cases a beautifully

reclaimed area is adjacent to an area newly reclaimed and not ready for use.

We have enjoyed success in planting conifer trees on mine dumps. The middle waste shale seems to be a good medium not only for grasses and forbs, but also for brush and tree species. When fertilized for a few years to help get the soil organisms functioning and vegetation established, the shales then seem to break down nicely into a good growing medium.

Mining, when planned properly and when the plans are followed, is compatible with other resources and uses.

MINE PLANS: BASIC REGULATORY REQUIREMENTS

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Under the amended Mineral Leasing Act of 1920, as far as it applies to phosphate, no requirement exists for the submission of mining or operation plans. However, regulations from the Secretary of the Interior require that:

> Before conducting any operations under a permit or lease, the operator shall submit, in quintuplicate, to the authorized officer for approval, an exploration or mining plan which shall show in detail the proposed exploration, prospecting, testing, development, or mining operations to be conducted . . . . No operations shall be conducted except under an approved plan.

These regulations are in Title 43 Code of Federal Regulations, Subpart 3572. Prior to August 12, 1983, they were found in Title 30 CFR Part 231. The change was due to the 1982 merger of the Bureau of Land Management and Minerals Management Service and the resultant recodification of parts of Title 30, Mineral Resources, to Title 43, Public Lands: Interior.

The 43 CFR Part 3500 regulations apply to the solid leasable minerals other than coal. Specifically, these minerals are potassium, sodium, sulfur, gilsonite, phosphate, and the acquired-lands hardrock minerals. These regulations also apply to Indian reservation lands in concern with Title 25 CFR. Significant operations currently covered by the regulations are the trona deposits in Wyoming, potash deposits in New Mexico, the lead-zinc deposits in Missouri, and phosphate deposits in Idaho. Because of this diversity, the regulations are general and provide a lot of latitude to the authorized officer as to what he or she deems an acceptable mine plan for a particular deposit.

An integral part of mine plans are maps. While the regulations do not specifically include the map requirements under the operating plan section, they do address map requirements on an as-required basis.

The mine plan, including maps, is reviewed and approved by the authorized officer after consultation with the other involved agencies, usually the Forest Service or Bureau of Indian Affairs. If modifications of the plan are required, the regulations provide that the authorized officer will indicate what these are in order to make the plan acceptable.

To eliminate misunderstandings and undue time delays, the operator should develop a preliminary mine and reclamation plan for review and discussion purposes with the authorized officer and other appropriate agencies. This in the long run will save time and heartburn for all parties involved.

THE COMPUTERIZED MINE PLANNING PROCESS: STATE OF THE ART

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Use of computers is fast becoming standard practice and has largely replaced manual effort in mine planning. Most of the programming is based on manual methods. The advantage of the computer over manual methods is speed, allowing rapid analysis of alternates. This in turn allows timely evaluation of multiple operating options in developing mining plans.

MODELING

The first step in computer application to a given deposit is to develop a mineral inventory model, sometimes called a geological reserve model, of the mineralized zone. Various methods are applicable and the net result is a mathematical description of the ore body suitable for evaluation of ore quantities and grades in relation to a particular geometry for mining.

This model, of course, attempts to represent reality, optimization processes applied to it will optimize the model and not necessarily reality.

ESTABLISHMENT OF MINABLE ORE RESERVE

The ore reserve is that part of the mineral inventory that can be mined at a profit. This requires establishment of economic pit limits. The most common methods used are:

1. Break-even stripping ratio.--This is production value minus production cost of ore divided by the stripping cost per ton of waste.

2. Cut-off grade.--This is the lowest grade at which an ore body can be profitably exploited.

3. Ultimate pit mining slopes.--Established from experience or geotechnical studies.

Use of computers in this process can be interactive between engineer and computer, or automated. The lastest advances are in interactive engineer-to-computer graphics applications. When these become more widespread they should replace the present systems.

LONG-RANGE PLANNING

Long-range planning supplements the ore reserve and ultimate pit design plans. It relates the geometry of mining to the ultimate pit limit by creating phase designs. These are shape-oriented rather than time-oriented. The phase designs are then used as a basis for long-range time-oriented mining plans. The long-range plans quantify the amount of waste stripping required to maintain ore continuity at the required grade. These plans are probably annual for the first 5 years and for longer periods until the ultimate pit limit is reached.

SHORT-TERM PLANS

These are for less than 1 year. Here, computers allow detailed equipment and production scheduling and budget preparation.

The primary problem in short-term mine planning is the large number of interrelated factors and the time-consuming calculations. Use of computers, usually associated with graphic digitizers or interactive terminals, allows fast calculation and permits rapid revision for changing operating conditions.

PHOSPHATE MINE WASTE DUMP LOCATION, DESIGN, CONSTRUCTION

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Caribou National Forest
Pocatello, ID

Waste disposal is one of the most, if not the most, costly operations in open-pit mining. In the Idaho phosphate field, 6 to 9 tons of waste must be moved for each ton of ore produced. Dumps must be constructed to be permanently stable and vegetated to minimize erosion, and material eroded must be contained on site.

I. Site Selection

A. Alternative sites needed to comply with National Environmental Protection Act (NEPA) regulation, should be selected and proposed by operator

B. Selection criteria

1. Operators: a. haul distance, b. relative elevation, c. capacity, d. foundation stability.

2. Surface Management Agency (SMA)

a. Impacts on surface resources: water, wildlife and wildlife habitat, timber, range, recreation, esthetics, socioeconomic, and threatened and endangered species.

b. Amenability to revegetate: stability, slope, mantle of middle waste shale and topsoil.

The SMA makes its selection through the NEPA process using one of three approaches: categorical exclusion (CE), environmental assessment (EA), or the environmental impact statement (EIS). The scope and magnitude of expected impacts dictate which must be used. Mine waste dumps as part of a mining plan are usually addressed in an EA.

II. Dump Design

A. Clearing

1. All merchantable timber, poles, and posts will be timber harvested. All other trees within dump site are to be cut. Harvest of firewood is urged.

2. A barrier of slash is to be built at final dump toe in each drainage channel.

3. Grubbing and removing of other vegetation are not required.

4. Normal accumulations of snow need not be removed.

B. Drainage

1. For beneath dump drainage, continuous rock drain leading to the final toe of the dump must be constructed in drainage channels within the dump site.

2. Surface flow entering the dump site must be provided an adequate and permanent channel under, over, or around the site.

3. The top surface of dumps must be constructed so as to direct surface flow away from the steep faces to some safely controlled means of disposal.

C. Placement of waste rock

The Forest Service has three major concerns in the placement of waste rock:

1. Only coarse durable rock will be used in drainage structures or channels.

2. Dump surfaces will be covered with a minimum of 5 feet of waste shale as a plant growing medium.

3. Mass stability of finished dump is accomplished.

There are two schools of thought. The civil engineer's approach is to build either an earth fill dam or a highway fill. Waste would be placed in shallow layers starting at the bottom and compacting each layer in sequence. This approach is not compatible with the characteristics of waste rock. It would be excessively costly. The end use does not warrant such stability as could be achieved.

The miner's approach is to dispose of waste rock in the most economical and safe way possible within the constraints of the equipment used and the topography. A scraper operation would lay down relatively shallow layers with the only compaction being incidental to the movement of the scrapers. A shovel truck operation may dump waste rock from a single high level or by dumping on a series of levels usually starting with the highest level. The only compaction obtained is incidental to the trucks and other equipment operating at the dumping levels.

The Forest Service has no quarrel with the miner's philosophy of waste dump construction when the three conditions mentioned earlier are met--provisions for drainage and for mass stability and a surface cover of shale as a growing medium for vegetation.

D. Final shape of dumps

1. The Caribou National Forest has a policy with two simple requirements for the shaping of waste dumps. These are easily understood and readily monitored.

   a. The dump face will have no concave surfaces, avoiding concentration of runoff and consequent erosion.

   b. The dump face will not be steeper than 3 horizontal to 1 vertical. This will:

      (1) Permit use of agricultural type of equipment in seedbed preparation, fertilizing, and seeding.

      (2) Permit equipment to move on the contour and thus minimize the potential for erosion.

      (3) Automatically present a high degree of mass stability.

2. Industry has a fundamental problem with the 3:1 slope:cost of shaping.

A dump face slope of 2.5 horizontal to 1 vertical is about as steep as can be ripped, harrowed, fertilized, and seeded using currently available equipment. However, at this slope the equipment can move only up and down the slope, setting up ruts that channel runoff water and promote erosion.

The Caribou has stipulated that finished slopes will not be steeper than 3:1 because:

   a. Ripping, harrowing, fertilizing, and seeding can be done on the contour, setting up ruts that inhibit channeling of runoff and enhance infiltration.

   b. Greater mass stability is obtained with a 3:1 slope than with a 2.5:1 slope.

   c. Cost per acre for revegetation is less than for steeper slopes.

A comparison of effort needed to shape an angle of repose dump to a 3:1 slope is shown in sketches 1, 2, and 3. These sketches use simplified geometry to establish a relationship that will be valid in the more complicated geometry that the miner will encounter.

Sketch 1: A vertical, longitudinal section through a waste dump at a uniform angle of repose of 1.4:1.

Sketch 2: Same section shaped to 3:1 slope required by the Forest Service. The effort required for the shaping is calculated and equated to 100 percent for comparison with other slopes and conditions to follow.

Sketch 3: The same section shaped to 2.5:1 slope. Here the shaping effort is calculated to be only 72 percent of that required for the 3:1 slope.

III. Means of Reducing Shaping Costs

A. Dumping on decline.--Sketch 4 shows a 10 percent decline of the dumping level from the point where the 3:1 slope intersects the dumping level out to the angle of repose slope. The shaping effort calculates to be 80 percent of that shown in sketch 2.

B. Saurman dragline system.--Sketch 5 shows the range of bucket-travel up to 1,000 ft, buckets to 20 yd^3. Advantages: (1) only bucket travels, creating less energy waste, (2) less inhibited by weather and wet material.

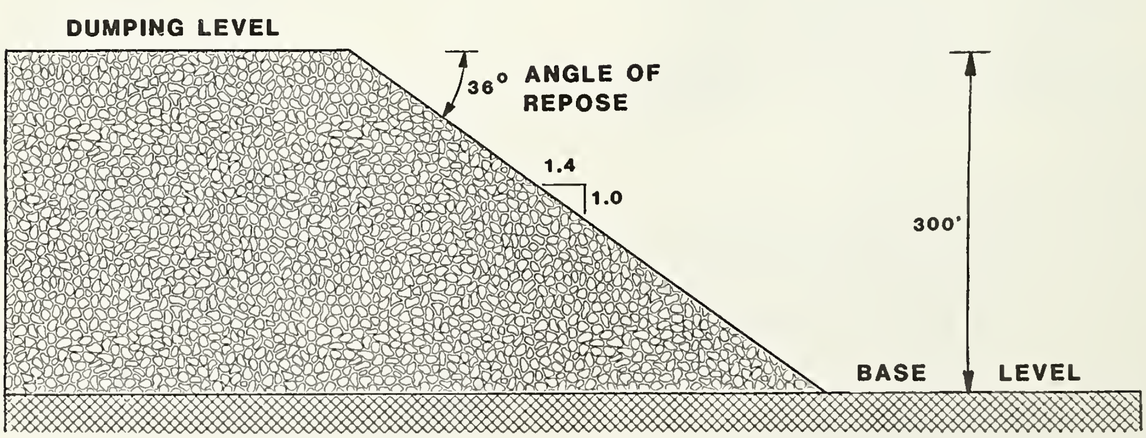
Disadvantages: (1) capital costs, (2) lack of mobility, and (3) lack of opportunity to keep in service year around.

C. Induced failure by water injection.--Sketches 6 and 7 show a proposed experiment that would require the combined talents of an experienced hydrologist and geotechnical engineer and a cooperating mining company. A bench would have to be cut at some calculated point in the progress of dump construction. Pipeline would have to be engineered to evenly distribute the water. Waste in which hydrostatic pressures could be built up would need to be placed in the vicinity of the distributor pipe and so forth. When all of the waste is in place, then water would be pumped in to create a condition of saturation that would induce failure. Sketch 7 shows concept of how profile might look after failure.

D. Planned placement.--Sketch 8 shows a waste dump planned for the head of a hollow and having convex contours on the face of the dump. Sketch 9 shows the outline of the finished dump superimposed on the original topography. Sketch 10 shows where the angle-of-repose crest should be located to minimize the effort required to shape the dump to the planned configuration. This crest line was located by drawing a series of vertical sections normal to the final crest, down to the original topography, and out to the final toe. The position of the angle of repose crest was adjusted on each section until the cut and fill were equal.

CONCLUSION

Each of the four suggestions in Section III may have potential for cost reduction. Perhaps by using variations or combinations of these suggestions, industry could accomplish its desired cost level while producing the 3:1 slope desired by the Caribou National Forest.



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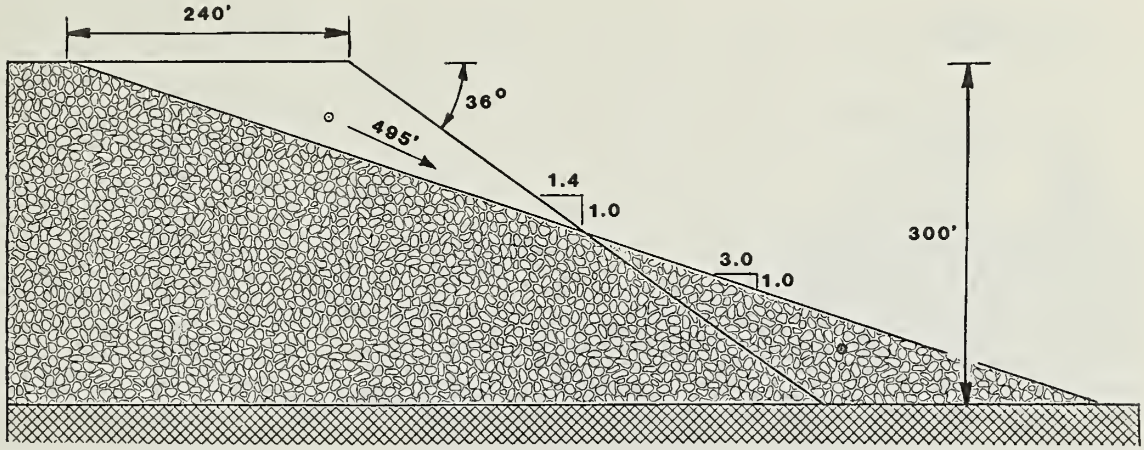
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300'
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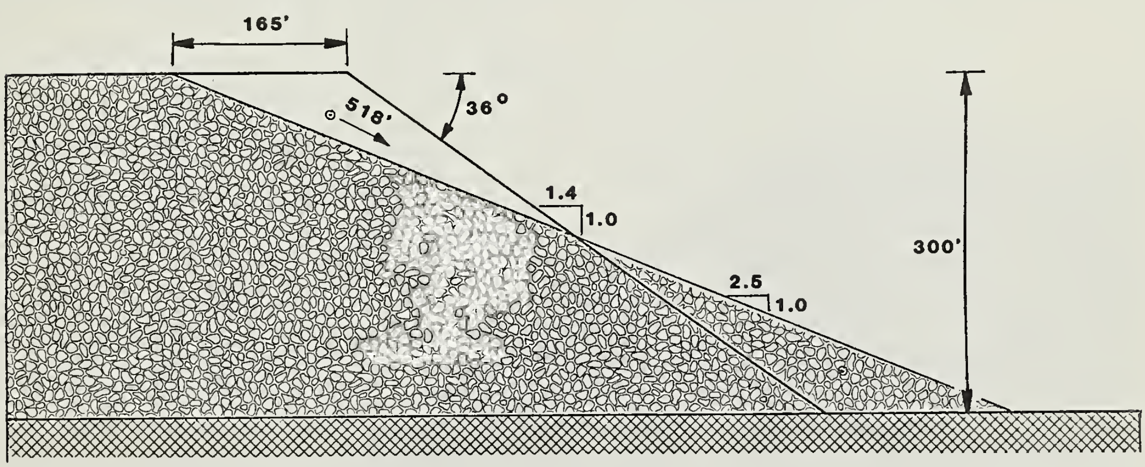
2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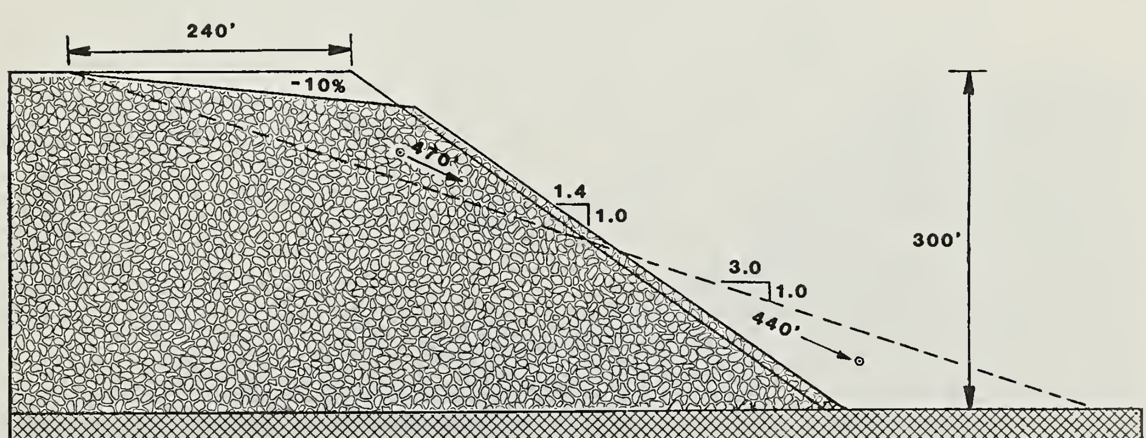
3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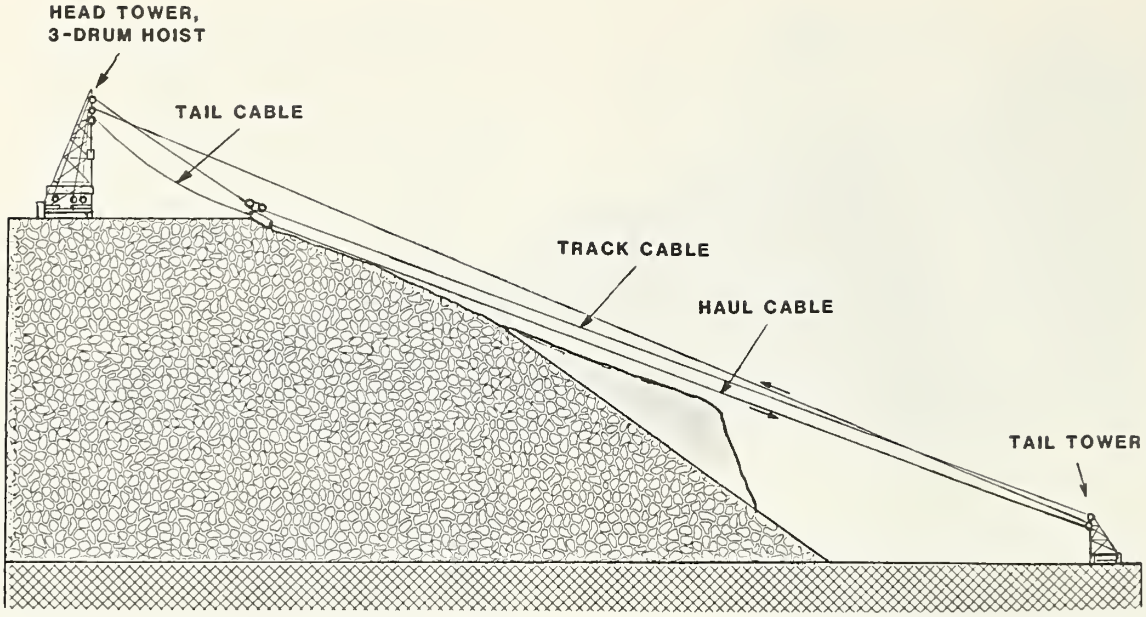
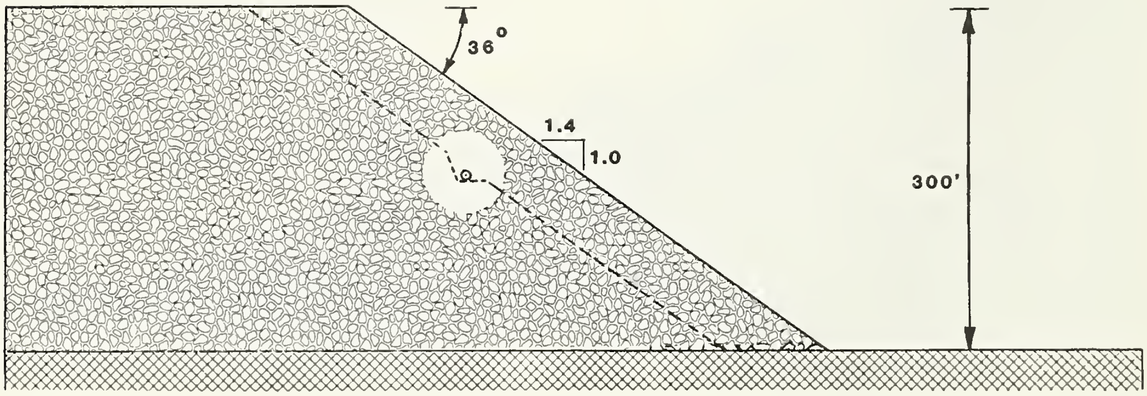
440'

4


HEAD TOWER,
3-DRUM HOIST
TAIL CABLE
TRACK CABLE
HAUL CABLE
TAIL TOWER

5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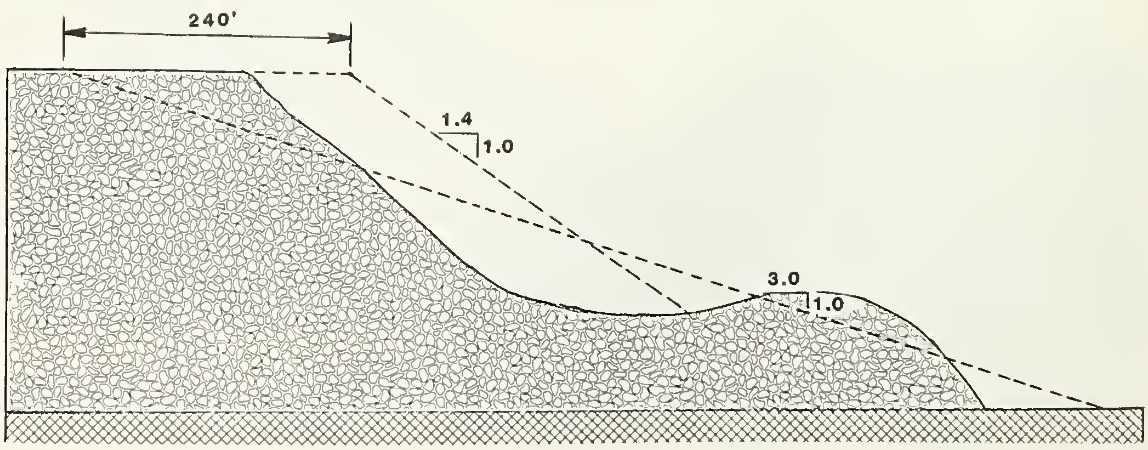
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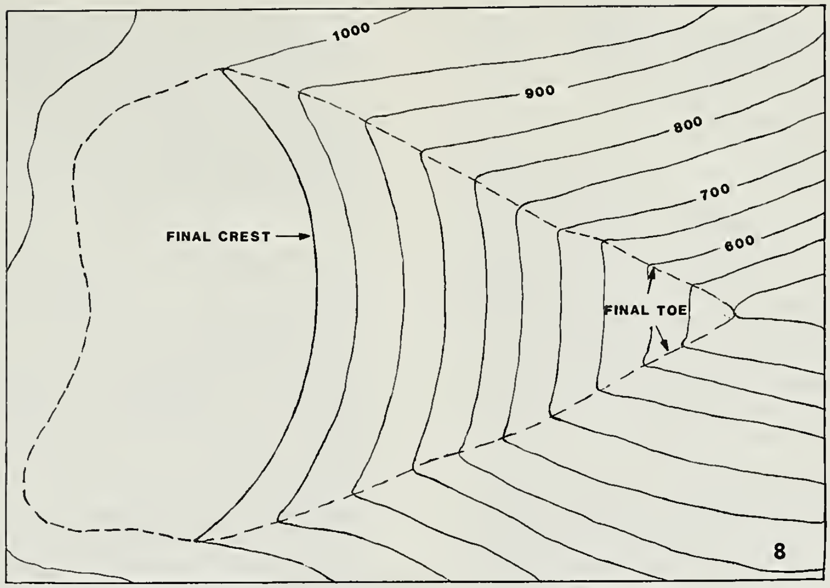
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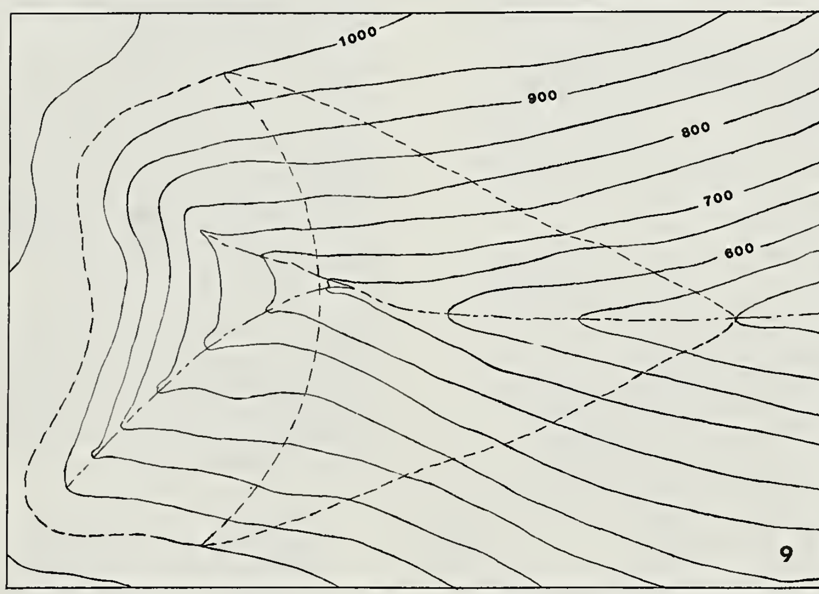
FINAL CREST
FINAL TOE
8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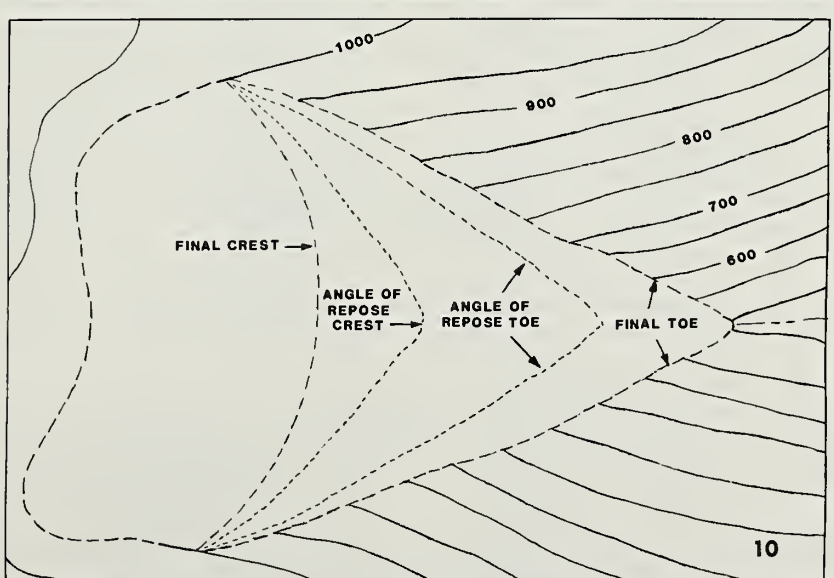
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FINAL CREST
ANGLE OF REPOSE CREST
ANGLE OF REPOSE TOE
FINAL TOE
10

RISK ANALYSIS: STRUCTURAL FACTORS

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College of Engineering
Utah State University
Logan, UT

Despite the care taken in siting, designing, and constructing an earth dam or other civil works structure, a residual level of risk of a catastrophic failure will remain. The event that causes the failure may be natural such as a flood or an earthquake, it may be related to the structure itself such as uneven settlement, core cracking, piping, or embankment of foundation slips, or it may be related to human factors such as incorrect operation or acts of war.

Following the Teton Dam failure of June 5, 1976, the civil engineering profession realized it had fallen behind other engineering disciplines in the application of risk and reliability analysis. However, the direct application of the procedures developed for risk analysis in the manufacturing industries, where many identical items are produced under conditions conducive to strict quality control, are generally not applicable to civil engineering projects.

The successful practice of geotechnical engineering requires judgment based on a knowledge of precedent as well as on understanding the principles of soil mechanics and geology. This fact is often used to support the argument that risk analysis and probabilistic methods have no place in geotechnical engineering. The opposite conclusion should be reached. Probabilistic methods and risk analysis have been developed specifically to cope with uncertainty in a rational way. Risk analysis procedures can be useful even when the design involves making many decisions for which some are based on analytical procedures, some on empirical procedures, some using precedent-based design rules, and some using strictly engineering judgment. Probabilistic methods are available that can consider uncertainty involving a judgment decision and include it in the same probabilistic analysis that considers the uncertainty in an analytically based decision.

A major area of geotechnical engineering for which the use of risk-based analysis procedures would be helpful is that of selecting between alternatives, whether it be for selecting alternative designs or for selecting alternative methods for mitigating a hazard. In the case of selecting an alternative, the problem involves evaluating the relative risk of the alternatives rather than the absolute risk. As an aid in selecting alternatives, risk analysis can be applied at all stages of project development from the initial feasibility studies through construction and into operation and maintenance. As the project progresses the data base for making risk assessment grows and the ability to evaluate risk increases. An absolute assessment of risk for a project as complex as an earth dam won't likely be possible for some time, if ever. However, a relative assessment of risk is all that is needed for selecting the best alternatives. It can help an experienced engineer determine whether an investment to improve one part of a complex structure will significantly reduce the overall probability of failure of the structure.

Figure 1 illustrates a risk-based method for establishing priorities for alternative dam safety improvements. The same general framework would also apply for selecting between alternatives for other types of structures such as waste embankments.

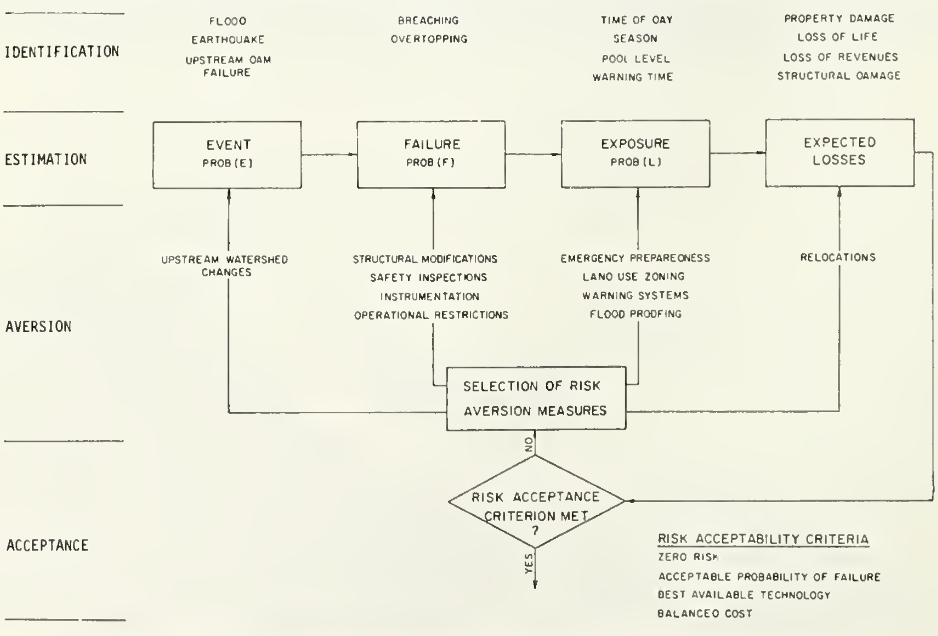

Figure 1.--Risk-based method for establishing priorities for alternative dam safety improvements.

HYDROLOGIC UNCERTAINTY AND RISK IN THE IDAHO PHOSPHATE AREA

Richard H. Hawkins, Professor of History
Utah State University, Logan, UT

Dan J. Kotansky, Graduate Student
Utah State University, Logan, UT

Eugene E. Farmer, Project Leader
Intermountain Research Station
Logan, UT

Hydrologic risk covers two major categories: first, technical uncertainty, which is not knowing what will happen; and second, probabilistic risk, which deals with not knowing when an event will happen.

In the phosphate area, technical uncertainty arises mainly from three phenomena: (1) errors in estimating remote events due to the unsuitability of available technical methods; (2) insecurity about the source processes of remote events, which can possibly lead to an unappreciated scale of flood flows; and (3) uncertainty on the altered hydrologic nature of mined lands and watersheds.

Available methods of estimating remote floods on ungauged areas are generally based on rainstorms. The techniques in vogue have been derived largely for eastern agricultural settings. Their suitability on western forest and range lands (and mined sites) has not been demonstrated. In fact, there is a growing body of evidence that they are unsuitable. A similar unhappy situation exists in the extraction of long-term sheet and rill erosion for western forest and rangelands. Also, there is not general, convenient, and well-developed techniques for estimating annual snowmelt floods from ungauged watersheds. Finally, the plethora of methods available and the information choices give a wide variety of answers. For the case of South Maybe Canyon, estimates of 100-year flood ranged from 17 to 436 ft^3/s, with a median of about 82 ft^3/s.

Source area processes in the uplands of the Intermountain West are important because of the vast differences in floods from snowmelt and rainstorms. Most annual floods arise from snowmelt and are of modest intensity because they are limited by snowmelt rates. However, extreme floods are often triggered by rainstorms and may be larger than an equivalent return snowmelt event by a factor of 10. Estimates of extreme floods drawn from analysis of short duration records that contain only snowmelt events, can lead to erroneous low figures and consequent underdesign.

Mined lands have altered hydrologic characteristics, such as depth, texture, cover, and composition, leading to altered infiltration capacities. For example, spoil placement in cross-valley fills creates new lands of unknown hydrologic characteristics. Experience thus far shows that while hydrologic responses from the lands are generally unpredictable, these new lands are surprisingly conducive to rainstorm runoff. The findings have been counterintuitive and contrary to design assumptions.

Probabilistic risk concerns the occurrence of an event within a given period. It is a realistic deeper look at the expected probability of a return event, lending itself easily to subjective decision making. Three illustrations may be given. First, a 100-year flood will not necessarily occur within a given 100-year period. Indeed, the probability of it happening is only about 63 percent. Second, to be 95 percent sure of including a 100-year event in the life of a project (or a hydrologic sample), a period of about 300 years should be planned! Third, to be 90 percent certain of not exceeding the capacity of a structure on a 25-year project life, a return event of about 240 years should be used. Such elementary approaches may be used in planning, designing, and administering to realistically appreciate the risk of proposed actions.

Of the above-described problems, the most fruitful research areas are the source area processes and the hydrologic nature of mined lands. These are more specific to Idaho phosphate lands, and solutions would be directly applicable.

SEISMIC RISK: MONITORING/RESEARCH NEEDS FOR EARTHQUAKE SURVEILLANCE

Walter J. Arabasz, Associate Director

Robert B. Smith, Director
University of Utah Seismograph Stations
Salt Lake City, UT

Two factors directly impact any seismological capability for providing detailed earthquake information relating to phosphate-mining areas in southeastern Idaho.

First, figure 1 shows seismic stations covering the southern Intermountain seismic belt. The phosphate mining area lies within a distinct "hole" in the distribution of seismic stations. (The "hole" chiefly affects the threshold of perceptibility, focal-depth control, and ability to provide continuous event detection.) What regional coverage does exist is the result of efforts by the University of Utah to integrate continuous seismic data from the university's Wasatch Front seismic network with data from stations operated by the Idaho National Engineering Lab, by Ricks College, and by an operator in southwestern Wyoming. Approximately 80 seismic stations are operated or recorded by the University of Utah, providing regional seismic coverage of the Intermountain seismic belt between Yellowstone National Park (stations

not shown) and southern Utah. Data are recorded and analyzed centrally in Salt Lake City in a computerized central recording laboratory.

Second, there has been a distinct lack of resources available for addressing earthquake problems in southeastern Idaho. For example, funding is currently provided to the University of Utah by the U.S. Geological Survey (chiefly for attention to the densely populated Wasatch Front urban corridor of north-central Utah), by the State of Utah (for seismic surveillance of the Utah region), by the U.S. National Park Service (for Yellowstone Park), and by the U.S. Bureau of Reclamation (for monitoring a specific proposed damsite east of Salt Lake City). Funding from Geological Survey as part of the National Earthquake Hazards Reduction Program is constrained by Federal guidelines relating to high-risk urban areas (the Wasatch Front), and State funding from Utah requires appropriate application to the Utah region.

The State of Idaho and Federal agencies with specific interests in earthquake-related problems in that state have to date shown little interest in fostering earthquake surveillance or studies in southeastern Idaho. Some past efforts by researchers at the university have been funded by the National Science Foundation (such as 1977 to 1978 studies by Bones and Arabasz in the Soda Springs area) and by Geological Survey (such as a special study of the 1982 swarm earthquakes near Soda Springs).

Although special earthquake studies have been pursued in the past in southeastern Idaho for academic interest or because of a justified response to significant earthquake activity, continuous surveillance demands the commitment of stable, long-term support from interested user groups. Earthquake monitoring invariably involves significant costs that can't be "bootlegged" indefinitely. Realistically, local "users" in southeastern Idaho must initiate any call for action and resources to augment local earthquake monitoring.

A wide range of possibilities exists for improving earthquake data acquisition and for fostering specific studies aimed, for example, at engineering applications or risk assessment in southeastern Idaho. Required funding similarly has a wide range (from a few tens to hundreds of thousands of dollars). If at some point there appears to be firm intent or resolve to address specific needs, seismologists at the university will gladly provide assistance or further detail. At a minimum, there appears to be a clear need for adding at least two or three seismic telemetry stations to fill the southeastern Idaho "hole."

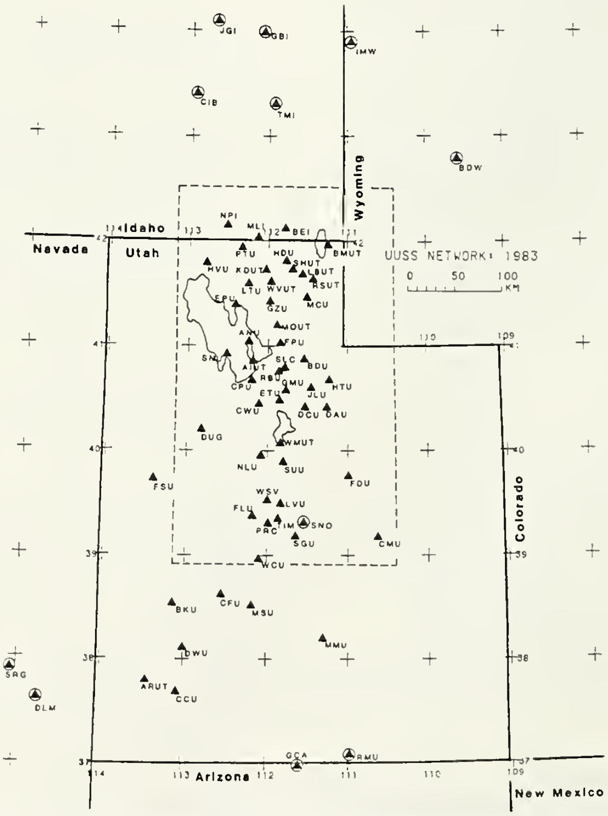

Figure 1.--University of Utah seismic network, February 1983. Triangles represent stations operated and recorded by the University of Utah. Circumscribed triangles represent stations maintained by other agencies.

RISK ACCEPTANCE

Eugene E. Farmer, Project Leader
Intermountain Research Station
Logan, UT

We all accept risk as a part of our everyday lives. But no one willingly accepts risks without commensurate benefits, and we all like to be aware of the risks that we accept or assume. In minerals extraction, both industry and land management agencies accept risk. Benefits also accrue to society, industry, and the government agencies.

How does the Forest Service accept risk? Risk acceptance by industry differs from the Forest Service both qualitatively and quantitatively. The risks are those structural, hydrologic, and seismic events that pose the danger of massive failure, overtopping, or severe soil erosion on overburden waste embankments.

While Forest Service managers take risks, we do not have a program for the analysis of risk. We have both formal and informal methods for qualitatively identifying a variety of risks. The formal methods, arising from the National Environmental Policy Act, are the environmental impact statement and the environmental analysis. The informal methods are developed through the process of reviewing mining plans, on-the-ground reviews by multidisciplinary identification teams, and the individual application of both practical and theoretical knowledge.

The Forest Service manages risk primarily through applying mitigating measures. These measures usually influence the length of the period that a projected impact may be active, or the location, and thus the severity, of the impact. Proposed mitigating measures are also given serious consideration from the viewpoint of cost to the operator and overall mine economics.

However, these methods of managing risk do not constitute risk analysis. In the context of managing risk through the application of mitigating measures, the real questions of risk and uncertainty are out of context and moot. For example, it makes little sense to ask a Forest Service land manager what is the design life of a given cross-valley fill, or to inquire about the design flood that will overtop the fill.

I believe that mine operators view risk quite differently from the Forest Service. First, the operators tend to be more quantitative. The design of waste embankments is frequently accompanied by a structural analysis of the factor of safety. This may or may not include seismic factors or other perturbations that relate driving forces to resisting forces. The semiquantitative factor of safety analysis is at the next level above the qualitative analysis of the Forest Service but still falls short of an analysis of the true risk and uncertainty. Second, mine operators must consider the price of their product in relation to the world and domestic market prices. These considerations usually dictate that waste embankments be constructed at the least cost. Finally, mine operators have a shorter time of responsibility for the developed mine lands, usually less than 20 years. Postmining land uses into the foreseeable future revert to the land managers.

Before the Forest Service can accept risk in a quantitative manner, we probably need: (1) a flexible national policy that can accommodate the changing technology, the likelihood of changing national preferences, and the possibility of changing institutional arrangements; (2) site-specific objectives developed at the local level with broad local agreement; and (3) reasonable performance standards that reflect true risk and uncertainty.

MANNER OF MATERIAL PLACEMENT: ROLLING HILLS AND PIT BACKFILL

Gordon Duncan, Mining Superintendent
Monsanto Company
Soda Springs, ID

The major landforms used for mining waste piles at Monsanto's Henry Mine are discussed, as are the waste pile design parameters, the method of construction, and the equipment used. Examples of each landform are presented along with advantages and disadvantages of each.

ANGLE OF REPOSE AND REGRADING

George C. Toland, Managing Partner
Dames and Moore
Salt Lake City, UT

I speak as a geotechnical engineer and not as an expert in land form construction or costs. My involvement with Simplot's flattening angle-of-repose slopes was requested because of three requirements proposed for the company's old dump by Federal, State, and private ownership. These requirements were: Federal--3 horizontal to 1 vertical; State--2.5:1; and private land--1.3:1. Our evaluations were not extensive but did involve embankment stability, erosion comparisons, and vegetation requirements.

Essentially, I believe there is no right or wrong answer to mine waste slope design. Mine waste embankments are like roadway embankments in that surface saturation is expected to cause problems. However, on roadway embankments I don't hear people suggesting 3:1 highway slopes, mainly because 90 percent of the mountain roads could

not be built at that slope. Reshaping mine waste on steep hillside areas has the same problem. There are many areas where the slope of the hillsides is steeper than 3:1.

These discussions lead to the conclusion that individual operations require individual design, and that abandoned dumps should be treated differently from new or continuing operations.

Two technical evaluations of the Idaho phosphate mine waste dumps deal with stability: the 1978 report by Utah State entitled, "Engineering Properties and Slope Stability and Settlement Analyses Related to Phosphate Mine Spoil Dumps in Southeastern Idaho," by Richard E. Ryker, Loren R. Anderson, and Rowland W. Jeppson; and "Stability of Non-Water Impounding Mine Waste Embankments," by Bruce C. Vandrey, published in 1980. Considerable data were developed in these publications, but they do not present a usable method for determining requirements for individual mining operations. Our evaluation for Simplot developed the stability and vegetation requirements for flattening to slopes of 2:1, 2.5:1, and 3:1. Our recommendations stated that a 2:1 slope appeared the best solution. However, I believe that angle of repose is the proper solution for most of the existing dumps at Conda.

The major concerns are cost and method of changing slopes from angle of repose to flatter slopes. Figure 1 shows the requirements to change to a 2:1 slope. Figure 2 shows requirements for changing to a 3:1 slope. You can see with a 2:1 slope you have to push material horizontally half the height of the slope, and with a 3:1 slope you must push the material horizontally a distance equal to the height of the slope. You can also see that I flattened the base of the natural hillside. This was necessary because in some locations you would need to flatten the hillside as well as the dump to achieve a uniform flattened slope.

Cost is difficult to assess. The use of a dozer to move material is economical to a certain push length. Beyond that, length scrapers or truck haul becomes more economical. Costs on moving mine waste are quite low by the yard, but by the millions of yards costs represent a major investment to mining companies with inactive dumps.

There seems to be only one item of concern with angle of repose dumps: continuing maintenance. The danger to the public is many times less than mountain road embankments. Therefore, the method of obtaining long-term maintenance seems to be the problem that needs solving. Some States have used maintenance bonds. A bonding requirement that reduces as the final slope decreases might be a long-term solution to the slope steepness requirement.

SLOPE REQUIREMENT

2 HORIZONTAL TO I VERTICAL

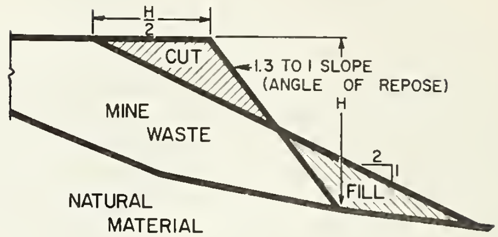

FIGURE I

SLOPE REQUIREMENT

3 HORIZONTAL TO I VERTICAL

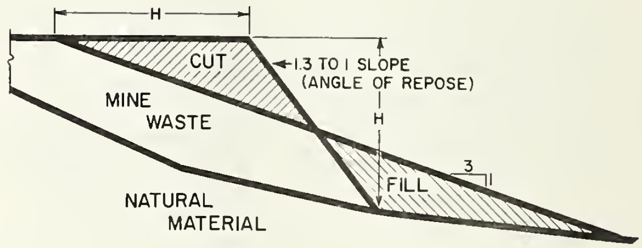

FIGURE 2

VALLEY FILL DUMP

Jim Frost

Donald D. Smedley
Mine Superintendents
Conda Partnership
Conda, ID

Whenever mining occurs, there are two resultant products: ore and waste. When mining was started on the southern portion of the I-04 lease, the disposal of waste rock presented a problem. This north-south striking ore body had only two disposal directions. The westward disposal would infringe on an elk calving ground that lies at the valley floor to the west of the lease, while Maybe Canyon to the east contained live water with several small springs. A waste rock storage area to the east was selected for a 30 MM BCY disposal site.

As live water would have to continue to flow beneath this structure when completed, a chert causeway was started by natural selection of elevated end-dumping to create a french drain that would ensure continued water filtration under the dump in the future. As this causeway approached the valley floor, a roll or "pooch" of alluvial/colluvial material was pushed in front of the advancing toe of the causeway. This roll could be partially attributed to saturated alluvial/colluvial material and the underlying Dinwoody Formation (a grey marlstone or shale). There was a concern that this roll would create a barrier to free flowage beneath the dump. The decision, in consultation with the regulatory Federal agencies, was to lay "in place" a chert core along the axis of the valley to further insure that water would not be impounded behind the structure and that the waste rock storage structure would not become saturated. This chert core was lain "in place" in advance of the continued elevated end-dumping as a french drain was placed on top of the chert core.

As the waste rock disposal area reached its ultimate height, the Intermountain Research Station began to conduct on-site research, co-funded by the Conda Partnership. This research included meterological data, piezometers and a well to determine porosity, neutron soil probes to detect any saturation, and stream flow gauge.

The research to date shows that water is flowing through and under the South Maybe waste rock storage area.

The cost of constructing an "in place" chert core was well above the per-BCY cost of the rest of the waste rock storage area. Because of an increased haul distance, the placement of 1 MM BCY in the chert core cost an additional $400,000, thus increasing the total mining cost for this open pit.

The Intermountain Station has provided valuable research showing that water is flowing through and under the South Maybe storage area, and that the structure has remained stable. Each waste rock storage area that is built will have different environmental and economic constraints that must be evaluated. Further study will be of value.

WASTE DISPOSAL EQUIPMENT: USAGE AND COSTS

Wayne L. Myers, Mine Manager
Gay Mine
J. R. Simplot Company
Pocatello, ID

All equipment discussed in this paper is currently in operation at Gay Mine. The J. R. Simplot Company's Gay Mine is within the Fort Hall phosphate district, one of 10 such districts in the Idaho phosphate field. The phosphate ore comes from the basal Meade Peak member of the marine Phosphoria Formation. Two grades of ore are mined and sent to the processing plants near Pocatello.

Because of the relatively small size of a typical fault block ore deposit at Gay Mine, there are usually two or three pits at various stages of mining at any one time. The required annual production of 1.8 million tons of ore could not be mined efficiently with a single pit. The multiple open-pit method is also needed to facilitate backfilling, an important first step in mined land reclamation.

Annual stripping of 6.3 million yd^3/yr of overburden (waste) is done primarily with:

1. A UH 801 Hitachi hydraulic shovel and Terex 33-11D (85-ton) trucks. The large shovel waste material is drilled and blasted prior to removal.

2. A mixed fleet of Cat and Terex 24-yd^3 scrapers and push dozers

3. A Cat 992 C loader and 85-ton trucks

4. Cat 245 mining shovels and Cat 769 trucks that remove waste interbedded with or immediately overlying the ore section

5. Small loaders and 35-ton trucks used as standby stripping units

Stripping costs are impacted by such factors as distance of haul, depth of the pit, condition of haul roads, blasted or unblasted material, density of overburden, operator skills, mechanical condition of equipment, weather, and visibility.

Because our haul roads and equipment are well-maintained and our operators are highly skilled, the major impacts on our costs are haul

distances and adverse haulage grades. Only 1983 direct costs are used in our calculations and include operating labor, lost-time labor, repair labor, service labor, operating supplies, repair supplies, and tire supplies.

Stripping production rates for a Gay Mine pit currently in production has been computer-developed to simulate comparative direct costs/yd^3 using various fleets. These costs have been further refined to show the difference between removing the top and bottom waste from this 350-ft deep pit. One-way distance of haul for top slice is 3,225 ft; bottom slide distance is 4,075 ft.

	Prod. rate Yd^3/h	Top slice cost/yd^3	Bottom slice cost/yd^3
Fleet 1- Hitachi 802 and support	650	$0.392	$0.415
Fleet 2- Scrapers and support	656	.788	.906
Fleet 3- Cat 992C and support	800	.426	.450
Fleet 4- Cat 245 and support	290	.995	1.072

In an effort to show the cost effect of increasing haul distance as the waste dump enlarges, we have added 1,000-ft and 2,000-ft level haul distances to each fleet. Increased costs for these distances are $0.01/yd^3 to $0.12/yd^3, dependent upon the fleet used.

RESEARCH NEEDS

Keith E. Evans, Assistant Station Director
Intermountain Research Station
Ogden, UT

Phoshate mining in Idaho began in 1909 at the Waterloo Mine and is expected to continue throughout southeastern Idaho for several more decades. The phosphate ore is from sediments that were deposited in a Permian Sea 225 to 289 million years ago. Southeastern Idaho contains approximately 35 of the Nation's phosphate reserves. Much of this reserve is close enough to the surface to be strip-mined.

Workers and equipment have followed the mining operations to reshape and restore the mining spoils. The stabilization of mine spoils has been primarily by revegetation with grasses, forbs, and shrubs. Revegetation technology has been successfully demonstrated by the mining industry. However, concerns about the stability and hydrology of mined lands persist.

Participants of this workshop were assigned to one of the four work groups to identify research needs:

1. Coordination of mineral development with surface resource management
2. Mine plans
3. Risk analysis
4. Mined land stabilization and costs

In compiling the results from these work groups, I have highlighted the critical research needs they identified, then have listed the other research needs and other subjects discussed by each group.

GROUP 1.--Coordination of mineral development with surface resource management

Critical Needs: There is insufficient knowledge about the potential of movement of fill material in relation to:

- Water retention characteristics of various waste materials
- Long-term hydrologic effects of roads and other transportation facilities
- Longevity of french drain usefulness
- Subsidence and slump characteristics of various materials and topographic shapes
- Options for design and placement of materials

Other Research Needs:

- Effects of earthquakes on large fills
- Angle and length of slope alternatives related to postmining uses
- Face drainage systems
- Effects of vegetation on dump stability
- Economical methods of backfilling
- Efficiency of earthmoving machinery
- Long-term monitoring of vegetation, water and other resources
- Postmining use of waste embankments, roads, powerline corridors, and other facilities
- Optimum mine abandonment procedures
- Defining Federal expertise needed in lease administration

Other Items Discussed by the Work Group:

- Long-term monitoring of succession
- Optimum fill slope length
- Durability of waste materials
- Growth medium and placement
- Angle and length of slope alternatives related to postmining uses
- Water retention characteristics of various waste materials
- Toxicity and heavy metal content of drainage
- Quantifying of mining values to the public
- Quantifying environmental and mining values
- Impacts on resources
- Long-term postmining use of waste embankments, pit area, roads, and other facilities
- Subsidence and slump characteristics of various materials

GROUP 2.--Mine plans

Critical Needs: Planning effectiveness is currently limited by insufficient knowledge in:
- -Information on slope stability and shaping
- -Continuous monitoring data from cross-valley fills
- -Computer applications to allow quick use of new information and to share information among companies and agencies.

Other Research Needs:

- -Cost effectiveness of transportation and mining methodology
- -Reclamation standards for highwalls and footwalls
- -Methodology to gather and exchange information on material handling in pits

Other Items Discussed by the Work Group:

- -Geological information
- -Stability of dip slopes
- -Foundation testing
- -Process technology for plant fertilization
- -Computer developed mine plans--optimizing recovery, software application
- -Role of the Intermountain Research Station
- -Maximizing resource recovery
- -Mining methods
- -Dump placement
- -Revegetation
- -Equipment for shaping
- -Esthetics
- -Transportation methodology--truck, train, slurry, conveyor
- -Monitoring baseline data for predicting water quality and sedimentation on proposed waste dumps
- -Monitoring water quality and sedimentation during construction, for the project's life, and after the project

GROUP 3.--Risk analysis

Critical Need: Risk analysis is inadequate because of a lack of knowledge on the effects that unique construction methods of mining waste embankments have on slope stability, hydrology, and settlement. Risk analysis research should quantify effects of possible events with information in the models on exposure, potential hazard, and probability of occurrence.

Other Research Needs:

- -Slope stability
- -Erosion
- -Floods

Discussion points of these main categories:

1. Slope stability

   a. Uncertainties

      - -buried vegetation, snow, and ice
      - -pore pressure
      - -shear strength
      - -soil properties
      - -rock properties
      - -construction methods
      - -seismic data

   b. Research approach
      - -general research
      - -site specific research
      - -is there a real identifiable risk?
      - -determine what applicable research exists
      - -knowledge gaps
      - -do unique construction methods influence risk?

   c. Priority research needs
      - -soil properties
      - -drainage
      - -buried vegetation, snow, and ice
      - -seismic data

2. Erosion

   a. Fundamental processes and properties of erosion
   b. Slope length and benches
   c. Sediment entrapment

3. Floods

   a. Meteorological data
   b. Characteristics of extreme events
   c. Unique effects of artificially created structures compared to network impacts
   d. Hydrological properties of artificially created surfaces

Other Items Discussed by the Work Group:

- -Probabalistic analysis
- -Expanded data banks to define theory and process within the heads of industry, regulatory agencies, and land management agencies
- -Long-term operation and integrity of french drains--effect of end dumping, hydrologic risks, and other hazards
- -Risks of liquification and earthquakes
- -Foundation stability
- -Slags dumped on steep slopes
- -Toxic materials
- -Infiltration (phreatic and piezometric)
- -Dust
- -Wildlife migration
- -Settlement and creep
- -Long-term monitoring
- -Economic data base
- -Short event storms and historical streamflows
- -Cultural
- -Geology

GROUP 4.--Mined land stabilization and costs

Critical Needs: To optimize economic efficiency of mining, information is needed:

- Technical data base (computerized) to share with different companies and agencies
- Sediment basin design including information on off-site effects
- Long-term multiple-use criteria and goals

Other Research Needs:

- Improved engineering practice
- Economic alternative analysis
- Postrehabilitation use
- Slope design related to erosion
- Hydrology studies

Other Items Discussed by the Work Group:

- Design guidelines
- Long-term stabilization, hydrologic, and seismic monitoring
- Economic modeling systems--making reclamation affordable to industry
- Making equipment available to industry
- Making technology available
- Liability into perpetuity
- Obligations on historic dumps and highwalls (grandfathering)
- Selecting dumps for 20-year monitoring
- Grasses for primary stabilization
- Uses of strip vegetation
- Wildlife data base
- Aspen trees and other alternative vegetation types
- Fencing to limit grazing
- Range management incentives
- Below-surface hydrological information needs
- Siltation
- Tie monitoring into design plans
- Effect of snow at the construction site
- Surface erosion models including weather factors
- Fertilization/depth of soil models
- Risk of fishery degradation in Blackfoot River
- Surface slumps
- Purchased water
- Breaking uniform slopes (roads, terraces, and so forth)
- Geological reconnaissance
- Subsurface studies
- Geological structure control
- Safety
- Cost of operation
- Value of stockpiling topsoil (cost-benefit)

AGENDA

for the

WORKSHOP ON ENGINEERING AND HYDROLOGY
RESEARCH NEEDS FOR PHOSPHATE MINED LANDS
OF IDAHO

Sponsored by:
The Idaho Mining Association

The Idaho Falls District of the
Bureau of Land Management, USDI

The Intermountain Research Station
and the
Caribou National Forest
Forest Service, USDA

June 4-6, 1984
Littletree Inn, Pocatello, ID

Monday, June 4

Registration - Lobby of Littletree Inn
Social Hour - Hosted by the Idaho Mining Association

Tuesday, June 5

Registration Continued
Welcome and Introduction
Chuck Hendricks
Forest Supervisor
Caribou National Forest

Keynote Speaker
R. Max Peterson
Chief, U.S. Forest Service
Washington, DC

Coffee Break

Panel Presentation - Coordination of Mineral Development with Surface Resource Management

Panel Moderator
Mr. Tom Roederer
Deputy Regional Forester
Ogden, UT

Reclamation Standards and Objectives
Tom Roederer

Mitigation of Long-Term Loss of Surface Resources: The Purpose of the Idaho Surface Mining Act
Stanley Hamilton
Director
Idaho Dept. of Lands
Boise, ID

Phosphate Lease Forms, Terms, and Stipulations
Gordon A. Aland
Government Affairs Supervisor
Monsanto Company
Soda Springs, ID

Tradeoff Evaluation: Accumulative Effects of Mining and Postmining Land Uses
Vaughn Francis
District Ranger
Soda Springs Ranger District
Soda Springs, ID

Lunch

Panel Presentation - Mine Plans

Panel Moderator
Barney Brunelle
Chief, Branch of Solid & Fluid Minerals
State Office
Bureau of Land Management
Boise, ID

Mine Plans: Basic Regulatory Requirements
Barney Brunelle

Computerized Mine Planning Process
Treve Hocking
Principal Mining Engineer
Dravo Corporation
Denver, CO

Phosphate Mine Waste Dump Location, Design, Construction
Ed Connors
Mining Engineer
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Tuesday, June 5 (continued)

Transportation Systems Including LANDFORM
Example for System Planning
Robert V. Kimball
Director of Mine Planning
J.R. Simplot Co.
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Break

Panel Presentation - Risk Analysis
Panel Moderator
Gene Farmer
Project Leader
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Logan, UT

Structural Factors
Loren Anderson
Associate Dean of
College of Engineering
Utah State University
Logan, UT

Hydrological Uncertainty and Risk
Richard Hawkins
Professor of Hydrology
Utah State University
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Seismic Risk
Walter Arabasz
Associate Director
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Salt Lake City, UT

Risk Acceptance
Gene Farmer

Wednesday, June 6

Panel Presentation - Mine Land Stabilization and Costs

Panel Moderator
Gordon Duncan
Mining Superintendent
Monsanto Company
Soda Springs, ID

Manner of Material Placement (Methods/Costs)
Rolling Hills and Pit Backfill
Gordon Duncan

Manner of Material Placement (Methods/Costs)
Angle of Repose and Regrading
George C. Toland
Managing Partner
Dames and Moore
Salt Lake City, UT

Manner of Material Placement (Methods/Costs)
Valley Fill Dump
Jim Frost and
Donald D. Smedley
Mine Superintendents
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Conda, ID

Waste Disposal Equipment: Usage and Costs
Wayne L. Myers
Mine Manager - Gay Mine
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Organization of Work Groups
Keith E. Evans
Assistant Station Director
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Each attendee will be assigned to a work group. Each work group will be assigned one of the four major panel presentation topics and will be led by the panel moderators:

Group 1 - Coordination of Mineral Development With Surface Resource Management
Tom Roederer
Group 2 - Mine Plans
Barney Brunelle
Group 3 - Risk Analysis
Gene Farmer
Group 4 - Mined Land Stabilization and Costs
Gordon Duncan

The group objective will be to discuss and identify research needs so the group leader can document and report those research needs to all workshop participants.

Work Groups

Lunch

Work Groups

Group Leaders Report of Identified Research Needs

Moderator
Keith E. Evans

Wrap-up and Summary

Were Objectives of Workshop Met?
Opportunities for Continued Cooperation.
Where Do We Go From Here?
Jack G. Peterson
Executive Director
and Chief Economist
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PHOSPHATE MINED LANDS OF IDAHO

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Evans, Keith E., tech. coord. Proceedings--workshop on engineering and hydrology research needs for phosphate mined lands of Idaho; 1984 June 5-6; Pocatello, ID. General Technical Report INT-192. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Research Station; 1985. 36 p.

Surface mining for phosphate in southeastern Idaho will continue for several decades. The emergent revegetation technology has been successfully demonstrated by the mining industry in large-scale applications. However, concerns about the stability and hydrology of mined lands persist. The objective of this workshop was to review current information and techniques and evaluate research needs in engineering and hydrology. Contributors came from industry, land management, and research.

KEYWORDS: mined land, phosphate, reclamation, hydrology, engineering, research needs

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The Intermountain Research Station, headquartered in Ogden, Utah, is one of eight Forest Service Research stations charged with providing scientific knowledge to help resource managers meet human needs and protect forest and range ecosystems.

The Intermountain Station's primary area includes Montana, Idaho, Utah, Nevada, and western Wyoming. About 231 million acres, or 85 percent, of the land area in the Station territory are classified as forest and rangeland. These lands include grasslands, deserts, shrublands, alpine areas, and well-stocked forests. They supply fiber for forest industries; minerals for energy and industrial development; and water for domestic and industrial consumption. They also provide recreation opportunities for millions of visitors each year.

Several Station research units work in additional western States, or have missions that are national in scope.

Field programs and research work units of the Station are maintained in:

Boise, Idaho

Bozeman, Montana (in cooperation with Montana State University)

Logan, Utah (in cooperation with Utah State University)

Missoula, Montana (in cooperation with the University of Montana)

Moscow, Idaho (in cooperation with the University of Idaho)

Ogden, Utah

Provo, Utah (in cooperation with Brigham Young University)

Reno, Nevada (in cooperation with the University of Nevada)